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"... for the encouragement of studies and investigations in Science Art Literature and Philosophy ..."

The Society traces it origin to the *Philosophical Society of Australasia* founded in Sydney in 1821. It became the *Royal Society of New South Wales* by Royal Assent in 1866 and was incorporated by an Act of the NSW Parliament in 1881. The Society exists for "*the encouragement of studies and investigations in Science Art Literature and Philosophy*": publishing results of scientific investigations in its Journal and Proceedings; conducting monthly meetings; awarding prizes and medals; and by liaison with other learned societies within Australia and internationally. Membership is open to any person whose application is acceptable to the Society. Subscriptions for the Journal are also accepted from non-members. The Society welcomes, from members and non-members, manuscripts of research and review articles in all branches of science, art, literature and philosophy for publication in the Journal and Proceedings.

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Editorial

In the last edition, I referred to the announcement by the Australian Research Council that it intended to withdraw the Excellence in Research for Australia (ERA) Ranked Outlets Indicator and to introduce a new system that does not use prescriptive ranks. It is pleasing that the *Journal and Proceedings of the Royal Society of NSW* is included in the new ERA 2012 Journal List. It is expected that this change will make multidisciplinary journals such as the Society's Journal and Proceedings more attractive to authors whose work extends beyond a specific discipline.

To this end, we are most fortunate to publish in this edition a paper by Lord May of Oxford on the role of scientific advice in influencing public policy. This subject is of particular importance given the extraordinarily complex and important challenges that the world faces in the 21st century regarding climate change, providing food for a population of over 7 billion people, and the challenges facing the world's financial system. Lord May's paper is particularly apposite in light of the Society's determination to play a larger part in the intellectual life of NSW through attracting papers that recognise the influence of art, literature and philosophy on the practice of science and, particularly, the way in which science influences art, literature and philosophy.

Complementing Lord May's subject is a paper by Professors John Boldeman and Richard Banati, two distinguished scientists at the Australian Nuclear Science and Technology Organisation (ANSTO), proposing the construction of a high-performance accelerator for radiation therapy and research and a paper by Justin Gilligan and Nick Otway at the NSW Department of Primary Industries in developing a means for identifying sharks species as part of managing the threat due to escalating shark fin demand. A paper by Patrick Michael explains important research done to improve the productivity of sweet potato, a dietary staple throughout much of the Pacific, and other tropical countries.

We are also most fortunate to have a biographical paper by Ragbir Bhathal, a former president of the Society, on the extraordinary career of Brian Schmidt, Australia's most recent Nobel laureate.

The Society's Council met recently to plan events for 2012. The programme will be announced early in the new year and will reflect the broader interest but continuing to emphasis the importance of science as central to the discourse. I am reminded of the Rede Lecture, *The two cultures*, delivered by C.P. Snow in 1959 (Snow (1959)). Snow lamented the gulf that had emerged between the sciences and the humanities to the extent that the two actually find difficulty in communicating with each another. Since then, if anything, the situation has got worse: well-reasoned scientific argument is rejected by non-scientists with very little rational justification; and many scientists struggle to find the relevance of non-scientific activities to the practice of their discipline. Perhaps, the Royal Society of NSW can provide a forum to bridge that gulf.

Snow, Charles P. (1959) *The two cultures*, (3rd edn., 1993), Cambridge University Press, Cambridge, UK

Donald Hector
Hon. Secretary (Editorial)

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Science advice and policy making

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Introduction

To borrow a phrase, we live in the Best of Times and the Worst of Times. This makes it particularly pleasing to see a resurgent Royal Society of New South Wales (RSN) playing a larger part in the communal life of the state.

It is the Best of Times in the sense that, thanks to our increasing understanding of how the natural world works, the average individual – in both developed and developing worlds – lives a longer and healthier life than ever before. Fifty years ago the average life expectancy on Earth was 46 years, whilst today it is 68 years. The counter-intuitive 46 year figure derives largely from the gap in life expectancy between the developed and developing worlds, which has shrunk from 26 years to a still disgraceful 12 years. Over the past 40 years, global food production has more than doubled, on only 10% more land; the continuing problems of malnourishment derive from inequitable distribution, a problem which has been with us since the dawn of agriculture.

The flip side of these advances is that population numbers continue to grow. Human numbers have trebled, to just on 7 billion, over the past 70 years. And although global average fertility rates are today roughly at replacement level, with the average woman having just less than one female child, the "momentum of population growth" is still carrying numbers upward toward around 9.8 billion by the middle of the century, as the currently pyramidal age-structure rounds out toward being more rectangular. Moreover, the ecological footprint stamped on the planet by the average individual's requirement for energy, food, and other materials and resources continues its upward growth. Humanity's overall ecological footprint today is around 50 times that at the publication of the Origin of Species, 150 years ago.

These problems could all, in principle, be solved. But such solutions require coordination and cooperation at the level of neighbourhoods and communities through to nation states. And there is little evidence, as yet, of willingness to acknowledge these needs for such cooperative activity.

The physical sciences are often called the "hard sciences", which is a misnomer: with their conservation laws and invariance principles; the physical sciences are the easy ones. It is not surprising that they developed first. Although the physical sciences ultimately underpin the biological sciences, the complexity of the evolutionary processes, whereby Darwin's "descent with modification" shaped the living world, makes for more difficult problems. Nevertheless, from molecular genetics to the structure and function of ecosystems, we have made great progress over the past half-century and more. The hardest problems, however, lie in the social sciences, which have all the complexity of the life sciences made yet more difficult by the fact that the subjects under study tend to react to being studied. This is especially unfortunate, because clearly the social sciences hold the key to solving our problems of collective action.

In what follows, I first sketch a subset of the challenges facing tomorrow's world: anthropogenic climate change; feeding more people; designing a financial system that allocates capital in a responsible and effective way. Against this background, I focus on the role of science advice in policy making, indicating some ideal principles along with the difficulties that commonly arise in practice.

Climate Change

Over our planet's half-billion year history, there are times when it may have been a ball of ice and snow (or something close to it: "slush-ball earth"), and other times when tropical animals roamed the poles. During most of humanity's tenancy of our planet, ice-ages came and went. But ice-core records show that levels of carbon dioxide in the atmosphere were steady at around 280 parts per million (ppm), give or take 10 ppm, since the beginning of the first cities. Indeed some people, noting that the past 10 millennia have been unusually steady, have argued that the beginnings of agriculture and the subsequent development of cities and civilizations is a consequence, not a coincidence.

The Industrial Revolution is usually taken to have begun in the 1780s, after James Watt developed his steam engine. As the industrialising countries began burning up fossil fuels at ever-increasing rates after the 1780s, carbon dioxide levels rose. At first the rise was slow. Reaching 315 ppm took about a century and a half. The increase accelerated during the 20th century, reaching 330 ppm by the mid-1970s, 360 ppm by the 1990s, and today is closing on 400 ppm. Such a change in the magnitude of the greenhouse gas blanket on this short time-scale has not been seen since the most recent ice-age ended, around 10,000 years ago. And we seem headed towards 500 ppm by 2050, approaching twice pre-industrial levels.

The long time lags that can be involved in these changes expressing themselves fully can be easily appreciated by physicists, but often seem counter-intuitive to others. Once in the atmosphere, the characteristic "residence" time of a carbon dioxide molecule is of the order of a century. And the time taken for the oceans to expand and come to equilibrium with a given level of greenhouse warming is several centuries. Deserving of emphasis is the fact that the last time Earth experienced greenhouse gas levels as high as 500 ppm was some 20-40 million years ago, when sea-levels were 100 m higher than today. Some have even argued that we should recognise that we are now entering a new geological epoch, the Anthropocene, which began around 1780. The InterGovernmental Panel on Climate Change (IPCC) has been consistently conservative in its predictions as to the extent to which global average temperatures would be raised by this thickening of the greenhouse gas blanket. Moreover, to those unfamiliar with the difference between daily temperature fluctuations and global average temperature changes, the suggestion that average temperatures may rise by 5°C or more by 2100 seems unworrying. But there is a huge difference between daily fluctuations and global averages sustained year on year – the difference in average global temperature between today and the last ice-age is only around 5°C.

The time-scales for some important non-linear processes involving climate change are admittedly uncertain. As ice-caps melt, surface reflectivity changes, causing more warming and faster melting. So the precise time-scale for ice-caps to disappear is unclear. As northern permafrost thaws, methane gas is released, which accelerates global warming. Increased freshwater run-off from glaciers in the Atlantic region will reduce the salinity of surface water, which in turn reduces its density. Such changes in marine salt balance have, in the past, affected the fluid dynamical processes which ultimately

drive the Gulf Stream, switching it off on ten-year time-scales (this is, however, seen as unlikely within the next century or so).

In the UK, following his party's election in 1997, Tony Blair's speech to the Party Conference majored on climate change. In 2008 the UK Climate Change Act was passed. It commits the UK and devolved administration Governments to setting and meeting carbon budgets, and preparing for climate change. The legislation also established, as an independent statutory body, the Committee on Climate Change (CCC). The Climate Change Act requires that the CCC report annually to Parliament on progress in meeting the carbon budgets; the third report was published in June 2011. The CCC also has an adaptation subcommittee, which published its first report in July 2011.

Not surprisingly, there exists a climate change "denial lobby", which is very well-funded and is also highly influential in some countries. Sadly, Australia appears to be one such country. This denial lobby has understandable similarities, in both attitudes and tactics, to the tobacco lobby that continues to deny smoking causes lung cancer. The book *Merchants of Doubt* (Oreskes and Conway (2010)) gives a well-documented account of the activities of, and techniques deployed by, these loose-knit groups of skilful (if unscrupulous) lobbyists allied with a few right-wing scientific ideologues. It is a category-error to call these people skeptics. In the early days, there was – as always in the early stages of scientific understanding – real need for skeptical scientific challenge. Even now, as noted above, there remain uncertainties about the timescales on which some important processes will operate. But, helped by computational power doubling every 18 months for the past several decades, it is not surprising that one recent study of top climate change scientists found "97%/98% agree on climate change". A separate study shows this statistic simply reflects the gist of the refereed scientific literature. And in the UK, public opinion broadly lines up with the scientific consensus, with a recent professional poll finding 80% agreeing that climate change is real and serious.

Feeding Tomorrow's World

The Green Revolution in agriculture, referred to in the opening section of this paper, has for the past several decades enabled food production roughly to keep pace with global population growth. There are, however, worrying signs that these advances are reaching a plateau. Furthermore, although the Green Revolution has been "green" in the sense of being increasingly effective in turning photons from the sun into food, it has been far from "green" in the sense of being environmentally friendly. What is needed – both to feed still growing populations and to do so in less environmentally damaging ways – is a "Doubly Green Revolution" (Conway (1997)). In short, we could not feed today's population with yesterday's agriculture, and it is doubtful whether we can feed tomorrow's with today's agriculture. The Green Revolution's doubling of food production involved, amongst other things, massive inputs of fossil-fuel energy subsidised fertilisers; around the globe, more than half of all the atoms of nitrogen and of phosphorus in green plant material that grew last year came from artificial fertilisers, rather than the natural biogeochemical cycles that built the biosphere and which struggle to maintain it. The consequent impacts of habitat loss and other disturbing factors upon the diversity of plants and other animals with which we share our planet is only just beginning to be fully appreciated.

I share the view that the solution to this dilemma lies in using our remarkable advances in understanding the molecular machinery whereby plants and animals assemble

themselves, to design crops that are optimally adapted to their environment, rather than – as at present – wrenching their environment to suit them by using fertilisers, herbicides, pesticides and other artificial interventions. Although today's crops have undergone eons of genetic modification by selective plant breeding, so that only an expert can recognise their wild ancestors, there is currently much resistance to using today's greater understanding of molecular genetics deliberately to produce crops with desirable characteristics. Indeed, the words "genetic modification", or GM, have for many people become a term of derogation, in ways which make no scientific sense. There is admittedly some justification for this, in that – in contrast to the Green Revolution, which derived from public money and was focused on public benefits – the first applications of the new GM technology were funded privately (by firms such as Monsanto), and could be seen as primarily serving corporate interests.

By now, however, 25 years of research funded by a wide variety of organisations (including the EU, private charities, research councils, etc), have found no scientific evidence associating GM plants with higher risks for the environment or for food safety than conventional plants and organisms. This of course does not prove that GM methods are 100% safe (which is also true for any novel food) but makes it clear that there is no contrary evidence. North America, China, South America and India are actively exploiting the opportunities offered by GM, producing crops which raise yields in a sustainable way, increase resistance to diseases and pests, and are better adapted to environmental stresses such as drought or low temperatures. In 2010 there were something like 15 million farmers planting GM crops, covering well over one million square kilometres.

Europe, and the UK in particular, along with Australia have been among the leaders in developing this beneficial new technology. But opposition from well-intentioned, but woefully and wilfully uninformed, NGOs and other campaigners has so far hindered these countries – and their environments – from reaping the consequent benefits.

Optimising the Financial System

Recent events have strongly suggested that the financial system, upon which all economies depend, is not optimally designed. Of course, it never was "designed", but has evolved over many centuries, guided by changing customs and beliefs, which have rarely (if ever) been grounded on evidence that would pass muster in the physical or biological sciences.

In particular, the broad regulatory framework set out in Basel I and Basel II focused on issues of minimising risk for individual banks. Here I am using the word "bank" as shorthand for a wide variety of financial institutions. It is now increasingly recognised that the diversification thus encouraged – essentially taking advantage of the statisticians' Central Limit Theorem to spread risks more widely – was indeed sensible for each individual bank, viewed in isolation. But the consequence for the banking system as a whole was to diminish diversity, as banks became both more similar in their asset holdings and more densely interconnected. A series of papers and speeches by Andrew Haldane, the Executive Director of Systemic Risk at the Bank of England, sets this out clearly (Haldane (2009a, 2009b)).

Not surprisingly, much work is now focused on systemic risk, as distinct from risk to individual banks. The basic idea is to make it more difficult for the failure of any single bank to propagate throughout the banking network, producing cascades of collapse. For example, in the UK the distinguished economist Sir John

Vickers is chairing an Independent Banking Commission, which will publish its recommendations in September 2011.

In broad terms, such bodies, whether in the USA, UK or EU, seem likely to recommend that all banks be required to keep larger capital reserves and/or other forms of liquidity than has recently been the case. Recognising the disproportionate influence of the biggest banks, which are akin to what epidemiologists call "superspreaders" of infection, there is also the strong suggestion that such banks hold relatively larger capital reserves; the contrary has been the recent practice. Other suggestions are that leverage levels be hauled back well below those of recent years, and that the magnitude of capital reserves be countercyclical (larger in boom times, lower in bust times, again to the contrary of the recent past).

All these suggestions are being fiercely resisted by the banking community. Chanting mantras about "invisible hands" and "perfect markets", the bailed-out banks want to get back on their roller-coaster and ride it. We do well to remember Stiglitz's maxim: "the reason the invisible hand is invisible is that it is not there".

Essentially all the above activity focuses on systemic risk. Undoubtedly important though this is, my view is that equal attention should be given to the ingeniously complex financial instruments – Credit Default Swaps (CDS) and their kin – which precipitated the initial crisis (Haldane and May (2011)). In retrospect, it is clear that the theory which provided the basis for pricing these instruments was grossly flawed. And the Credit Rating Agencies were naïve, not to say extraordinarily incompetent, in not recognising this. Personally, I would like simply to forbid trading in instruments which were so complex as to defy intuitive understanding. On the other hand, I do recognise the difficulties here: who decides what is too complicated?

Going one step further back to fundamentals, a very thoughtful essay by Benjamin Friedman (Distinguished Professor of Political Economy at Harvard University) (Friedman and Solow (2011)) poses the question: what is the basic role of financial markets in a free-enterprise economy? Friedman sees the task "to be one of allocating the economy's scarce investment capital". He notes that "the financial system also provides other services that are valuable. But I highlight the allocation of the economy's capital because for all of the financial system's other functions [here he gives examples] we have well-established alternative models".

Having thus defined the task, he goes on to ask – in the light of recent events – whether the economy is indeed being well served by the financial system. His answer is a decisive "no". First, with detailed examples, he notes that "assets were mispriced and resources, therefore, were badly allocated". Second, he asks "how much it is costing us to operate this financial system that allocates our capital". The facts are that thirty years ago, the cost of running the financial system "was 10% of all the profits earned in America". Fifteen years ago, this had risen to somewhere between 20% and 25% of all such profits. And in the mid-noughties, before the crisis hit, "running the financial system took one-third of all profits earned on investment capital". And this figure is an underestimate, because it excludes such items as the costs of property (essentially always on prime sites), not to mention lobbying.

In summary, Friedman goes deeper than addressing systemic risk, deeper than asking about the dodgy financial instruments that initiated systemic failure, to ask the truly fundamental question of how cost-effective is the present system for allocating capital.

Science Advice and Policy Making

In the foregoing, I have deliberately chosen three different areas, all controversial, where

scientific issues intersect with policy choices. For climate change, we have unambiguous scientific understanding, which calls out for activity both to ameliorate and to adapt. This, however, conflicts both with some business interests, and also with some intransigent (often politically right-wing) opinions based on beliefs rather than facts. For tomorrow's food and GM crops we again have conflict between established science and firmly-held opinion, but here the opposition is mainly from voluntary bodies such as NGOs, whose motives are generally well-intended (and often left-wing). For the financial services, the science (itself largely social science, but increasingly merging with recent physical-science led advances in "complex systems") is by no means fully understood. But the clear, if less than definitive, changes being considered by regulators are being strongly resisted by the financial community, who are being extremely well-paid when things are going well, and where the costs of bad times fall not on them but on the tax-payer.

In these three varied examples, along with very many others, we face the question of how do we give science advice for policy making? Most importantly, recognising that we will never have unanimity even if the scientific understanding is very secure, how do we handle such questions in ways which will generate public confidence in the outcome?

My answer here is an outline (and in parts a plagiarism) of more detailed suggestions given in my 2002 and 2005 Presidential Addresses to the Royal Society (May (2002, 2007)), itself based on earlier experience as the Chief Scientific Adviser to the UK Government, 1995-2000.

In principle, the answer is simple. Bring together the appropriate experts, consulting widely and deliberately seeking and considering dissenting opinions. Identify conflicts of interest, but do not necessarily use them as grounds to exclude individuals. And, above all, do all this openly. In many practical circumstances it is most important, yet most difficult, to separate the scientific facts and uncertainties – which must serve as a constraining background – from policy choices. In addition one should aim to assess the magnitude of risks, whenever possible, and to manage them proportionately. When real or perceived uncertainties remain, give people choices whenever possible (e.g., label GM food).

This relatively simple list of precepts was set out in the Protocols for Science Advice in Policy Making issued by John Major's Government in 1996. They have subsequently been reviewed and reaffirmed by Tony Blair's Government in 1997 and 2000, and Gordon Brown's Government in 2006 (at each iteration, they have grown bulkier, but their essentials remain unchanged). Independent support for such rules also has been provided (with acknowledgement of the originating 1996 document) by the Phillips Inquiry into BSE in 2000 and the House of Lords Science and Technology Select Committee in 2000 (the Jenkin Report).

Enunciating an ideal process is one thing. Embedding it as standard operating procedure is another. Indeed, given the apparent need to reincarnate such protocols for science advice in policy making at regular intervals, I suspect similar rules were enunciated prior to 1996 and that I am guilty of being unaware of them!

Quite apart from this "embedding" issue, there are other major problems in implementing such guidelines for good practice.

For one thing, as noted in all three of the varied "case studies" above, the scientific facts are simply not relevant for many individuals and groups whose views are determined by fixed, unquestioning ideologies (religious beliefs,

political doctrines, and so on). For such individuals, no observed fact or experimental result can ever prevail over the apodictic "truth" of a fixed belief or canonical revelation. Rather than engage with the scientific facts and uncertainties, such ideologues and extremists will pick and choose among them – or deliberately misrepresent them – in support of immutable beliefs. It is a category error to call such people "sceptics".

In the tumult of voices that can arise in such disputes, the media – print, radio, TV – are often unhelpful, for two reasons. First, their primary aim, which is not at all unreasonable, is to get your attention – to be read, listened to, watched. Only secondarily do they aim to inform; indeed, they cannot hope to inform if they do not attract your attention. Second, the media's praiseworthy desire for "balance" in reporting too often leads to presenting "two sides" as if reporting a soccer match. But this can, and often does, seriously misrepresent the state of the scientific evidence, where "one team" is the consensus view of the science community, and the "other team" is a tiny minority. For example, consider the debate about whether HIV causes AIDS. A research community in the order of 100,000 has by now established this as a fact. But a small travelling roadshow, including one Nobel Laureate, can still be assembled to deny it. And there are many other examples: from MMR vaccination in the UK to the essential reality of anthropogenic climate change (albeit with remaining uncertainties about the timescales and magnitudes of some nonlinear processes).

Furthermore, it is often difficult to make an accurate assessment of risks, and even when an accurate assessment can be made many people's subjective assessment is very different from the objective facts. Such subjective attitudes can create their own reality and impede effective policy actions.

Even a policy of "label and let the consumer choose" has its problems. For one thing, there is a question of individual risk versus collective risk (e.g., an individual may choose the health risk of smoking, but there remain associated risks of "passive smoking" for family or in public places; other examples abound, particularly in relation to vaccination policies and herd immunity). For another thing, there is the question of individuals making bad choices for dependent people, such as young children.

In all this, the job of science and scientists is to frame the debate clearly, making plain the possible benefits and costs – and the concomitant uncertainty. And making clear that cloud cuckooland is not a feasible choice. But when it comes to acting out the democratic drama of choice on the constraining stage thus set, science has no special voice. Scientists are just citizens on this stage along with others. The drama of choice is about values and beliefs, ultimately about what kind of world we want.

Such democratic choices, against a background framed by scientific facts and uncertainties, are hard enough. As emphasised above, it is more difficult when fundamentalist or other belief systems – or other motives more generally – seek to blur the distinction between constraining facts and democratic decisions. We should always keep in mind the cautionary tale of Indiana State, where in 1897 its Lower House voted to define the transcendental number π (the ratio of a circle's circumference to its diameter) to be exactly 3.2 to make things easier for the construction industry; their Upper House saved embarrassment by vetoing the bill.

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Lord May of Oxford is one of Australia's most distinguished mathematicians. He holds a Professorship at Oxford University and is a Fellow of Merton College, Oxford. He was President of The Royal Society (2000-2005) and before that was Chief Scientific Adviser to the UK Government and Head of the UK Office of Science and Technology (1995-2000). He had a key role in the application of chaos theory to theoretical ecology through the 1970s and 1980s. His many honours include: the Royal Swedish Academy's Crafoord Prize; the Swiss-Italian Balzan Prize; the Japanese Blue Planet Prize and the Royal Society's Copley Medal He is a Foreign Member of the US National Academy of Sciences and an Overseas Fellow of the Australian Academy of Sciences.

Lord May was presented with his Fellowship of the Royal Society of New South Wales at Government House on 29 April 2011 by the Society's patron, the Governor of New South Wales, Her Excellency, Professor Marie Bashir.

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Options for a light ion facility for hadron therapy and research

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Abstract

Several proposals have being prepared for the construction in Australia of a high-performance accelerator complex for radiation therapy and possibly research. In all cases the accelerators on which the facility would have been based required proton beams between 60 and 250 MeV. One of the previous proposals also suggested a more advanced accelerator system capable of producing carbon beams with energies variable from 120 – 430 MeV/amu. This paper summarises some of the physical processes involved in this treatment regime and considers some options for a possible Australian Facility.

Introduction

Cancer is a major burden on the Australian community with more than 100,000 cases reported each year. Cancer is a leading cause of death in Australia with over 36,000 people succumbing each year, in spite of a 30 percent improvement in survival over the last two decades. Cancers most commonly causing death are lung, prostate and colorectal in males and breast, lung and colorectal in women.

Although there are many kinds of cancer affecting different organs in the body, they all are caused by uncontrolled growth of abnormal cells. In a healthy individual, cells grow, divide, and die in a highly regulated fashion. During childhood, healthy cells grow and divide very rapidly until the individual becomes an adult. At this stage, cell growth slows until in most parts of the body, cells only divide to replace worn-out or dying cells and repair injuries. Cancer cells often travel to other parts of the body where they begin to grow and replace normal tissue. This process, called metastasis, occurs when cancer cells find their way into the bloodstream or lymphatic system of our body.

Cancer can be considered in two classes from the viewpoint of attempting to treat the patient:

- Generalized cancer where the cancer has spread from the original infested area to other parts of the body; and
- Localised Tumours.

Based on European Union data, the proportion of generalised cancers, when detected, constitutes about 42% of all cases. Of these, the mortality rate is about 88%. The two treatment regimes are surgery and chemotherapy although radiotherapy has value for palliative care. The remaining 58% comprise localized tumours where a variety of treatment regimes including surgery, chemotherapy and radiation treatment result in prolonging patient life by more than 5 years in 57% of cases. However, the morbidity is still very high and patient outcomes even with survival often leave the patient with some unpleasant physical consequences.

Improvements in radiotherapy over the last 20 years or so have contributed to increased survival but clearly there needs to be a major advance in treatment methods. Hadron Therapy (with protons, carbon ions) fills this gap and a large number of centres have been

built in recent years or are under construction (Jean-Michel Lagniel, PAC-07). Already more than 70,000 patients world-wide have been treated using this new method.

Physics Principles in Hadron Therapy

The physical advantages that ion beams (hadrons) have over X-ray beams (photons) was first pointed out in 1946 by Robert Wilson, 1946, although this had little impact on the medical community at the time. The first application of charged-particle beams took place at Lawrence Berkeley in 1954 and, after a long period of low-level investment, major development of the technique began with the installation of dedicated hospital facilities at Loma Linda and Massachusetts General Hospital.

Interaction Rate

The value of hadron beams in radiation therapy can be readily understood by considering the underlying physics of the interaction of various types of particles with human tissue. The best technology currently available in Australia utilises X-rays (photons). Photons which is the generalized word to describe electromagnetic radiation i.e., X-rays, gamma rays, bremsstrahlung, interact with matter via three processes, the Photoelectric Effect, Compton scattering and Pair production. In principle each photon interacts only once with the components of the body and, accordingly, the intensity of the photon beam decreases as it enters the body. Therefore the dose deposited in the human body has an exponential term of the following form:

$$I = I_o e^{-\mu_x} \qquad (1)$$

Thus, the maximum dose is delivered to the near surface of the body where there are healthy cells, there is no finite range to the dose distribution and the dose continues past the tumour being treated. Furthermore, because of the effective negligible mass of the photon, there is a large angular deviation of the photon beam as it passes through the body. On the contrary, hadrons e.g. protons and carbon ions have a different interaction process, principally coulomb interaction with target electrons in the irradiated body. The dose rate is given by the following expression:

$$\frac{dE}{dx} = \left(\frac{e^4 Z^2{}_{eff} Z^2 N}{mv^2}\right) * \text{other terms.} \qquad (2)$$

Simply, this means that a specific hadron ion gradually loses energy as it enters the body, slows down and finally stops altogether. At the end of its path it deposits a very large amount of energy as may be seen from the equation 2 above. This effect can readily be seen because of the term mv^2 in the denominator which becomes asymptotically small as the energy or velocity of the particle decreases. This effect which is called the Bragg Peak has been known for more than 100 years and was first pointed out by the two Australian scientists, William Bragg and his son. Furthermore, there is no radiation dose or energy loss after the ion has stopped. The key to the use of hadron beams is to adjust the energy of the hadrons so that they deposit their greatest energy in the tumour being targeted. The results of this difference in interaction are illustrated in Figure 1. The data for two ion beams, protons and carbon ions, and for traditional X-ray beams are shown. The dramatic increase in the radiation dose at the end of the carbon and proton pathways can be readily seen. Note that the doses in the figure are normalised to 1 at entry.

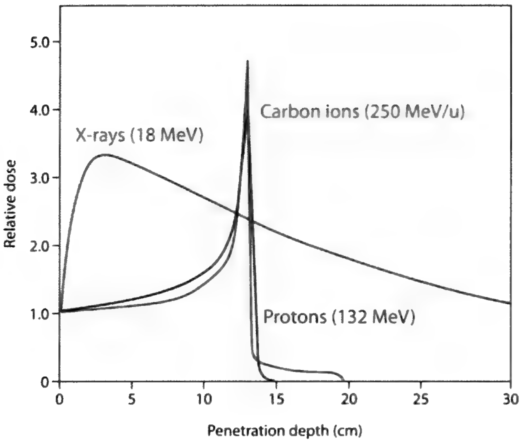

Figure 1: Normalised Relative Dose rates for X-rays, protons and carbon ions.

Linear Energy Transfer

Figure 2 shows the microscopic dose distributions for protons and carbon ions in water and DNA strand breakages for various energy ranges near the end of their tracks, (Haberer (2009)).

The dramatic increase in DNA double strand breakage observed with the carbon ions (right hand side of figure 2) shows that they are particularly useful in the treatment of radiation resistant tumours. With single strand breakage, DNA has the ability to repair itself but with double strand breakage this is no longer possible.

Lateral Deviation of Hadron Beams

A third important characteristic of the interaction of hadrons with human tissue is the lack of deviation of the hadron beam from the original beam direction. Figure 4, from a presentation by Thomas Haberer (2009), shows the lateral scattering of three hadron beams as a function of depth in water. The lateral scattering is much less than that with photons and the degree of lateral scattering diminishes with atomic charge.

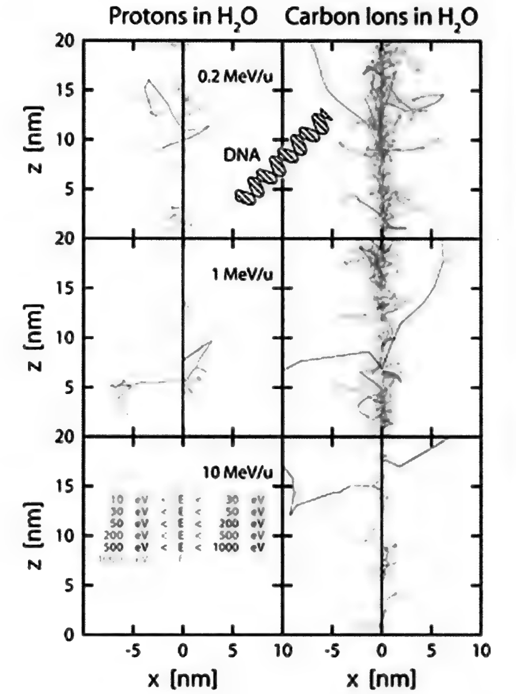

Figure 2: Microscopic Dose Distributions for Protons and Carbon Ions

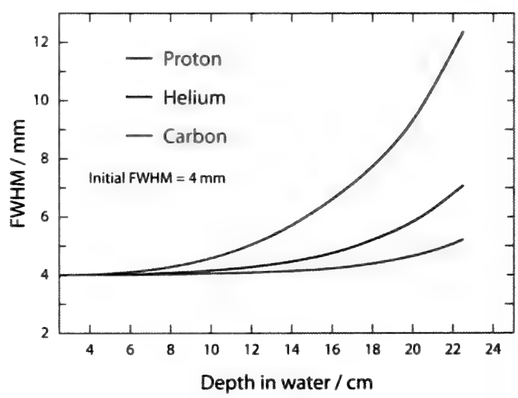

Figure 3: Lateral Deviations of Proton, Helium and Carbon Beams in Water

These properties of hadron beams translate into a far more targeted dose in many cancer cases. There are many examples in the literature of comparisons of dose distributions for hadron beams with those using the latest technology with X-rays (photons). Examples are not

reproduced here, but extensive studies will be found in Haberer (2009) and Boldeman et al. (2010).

Summary

The advantage that hadron therapy has over conventional radiotherapy can be summarized as follows:

- In the treatment process, the dose to healthy cells is reduced by factors between 3 and 10. This is particularly important in the treatment of children who have many years of life before them.
- Because the hadron beams can be controlled by magnets and because of the small deviation of the hadron beam as it enters the human body it is possible to target tumours very close to critical organs.
- It is possible to kill tumours that are resistant to normal electromagnetic radiation.
- Hadron beams are more effective and the number of fractions (i.e., the number of times a patient needs to attend the facility) is reduced.
- Side effects such as nausea are reduced.
- With modern accelerator systems it is possible to use magnetically controlled pencil beams to radiate the detailed shape of the tumour. This is called raster scanning.

Hadron therapy is particularly suitable for the treatment of deep-seated tumours that are located near to critical organs and which respond poorly to conventional X-ray (photon) or electron radiotherapy. Because of the significantly reduced dose to healthy tissues during a typical treatment, it is especially appropriate for tumours in children.

Scientific Applications of a Hadron Therapy Facility

The second possible objective in the installation of a Hadron Therapy and Research Facility follows from the many opportunities that such a facility would provide.

Radiobiological Research

The proposed facility would revolutionise research in many areas particularly in the biological sciences because of its ability to produce a variety of very energetic particles previously unavailable in Australia. These include the following areas of research:

- the study of low-dose effects;
- Radio Biological Effectiveness (late effects, genetic mutation, transformation) of high energy particles;
- determination of radiosensitivity of different tumours and normal tissues and molecular correlates;
- detailed study of chromosome damage;
- the importance of hypoxia;
- interaction of ion therapy and chemotherapeutic agents; and
- integration of biologic data into biological modelling for treatment planning.

Basic Research

In a number of areas of basic research the facility has the capability of extending Australian studies significantly. These areas include:

- proton – neutron production cross-sections;
- proton scattering cross-sections;
- nuclear cross section measurements;
- preliminary studies of ADS systems;
- decay spectroscopy, gamma spectroscopy;
- exotic beams and reactions;
- spectroscopy and atomic properties of relativistic ion systems;
- optical spectroscop;
- Atomic Collision Process;
- dielectric recombination measurements;
- heavy- ion ionisation processes;
- charge-state studies;

- coulomb fragmentation in heavy ion collisions;
- radiative electron capture studies; and
- heavy-ion stopping in matter.

Alternatives for an Australian Hadron Therapy Facility

The requirements for the hadron beams from any facility include:

- maximum penetration depth in the human body of approximately 32 cm;
- minimum penetration depth of 3.5 cm; and
- sufficient current to provide 2 grays of radiation to a targeted tumour in about 2 – 3 minutes.

With these principal requirements the hadron beams must be variable in energy:

- 60 – 250 MeV for protons; and
- 120 – 430 MeV/u for C12 beams.

The accelerator alternatives include:

- commercial cyclotron facility – protons only;
- commercial synchrotron facility – protons only;
- nationally constructed synchrotron facility – protons only; and
- nationally constructed synchrotron facility – protons and carbon beams.

An installation would require, besides the accelerator, a number of shielded treatment rooms plus the appropriate magnets to shape and transfer the beam to these areas. In most evaluations of the costs of the full installation, it is typical to include one treatment area for low energy beams, two places for horizontal treatment and another where the beam can be rotated either through 180° or at least have a vertical beam in addition to a horizontal.

In evaluating the alternatives and costs there is a number of over riding issues. The beamlines are to a large extent independent of the accelerator facility that drives them although the transfer magnets for a carbon beam are slightly more expensive

Cyclotrons, whether conventional or superconducting, require the smallest amount of space for the accelerator. A synchrotron providing protons only would be approximately 22m in circumference while the combined proton carbon beam would be 77 m in circumference. All of the treatment options mentioned above would be required for a commercially-based proton synchrotron and with some modification a cyclotron-based facility. Furthermore, the buildings which comprise a major component of the costs of a facility are not too different depending on the options. However, the footprint of a combined carbon- proton machine is about 20% larger.

A careful evaluation has been made of the costs of a combined proton carbon synchrotron and appropriate supporting facilities at $180 M, Boldeman et al 2010. If a proton only synchrotron were installed, the costs would reduce by approximately $20 M, because of the reduced number of magnets and the smaller area required for the accelerator. The installation of a cyclotron for the accelerator complex would result in an additional reduction of about $5 M.

The layout of the Heidelberg Ion Therapy Facility (HIT) at the University Hospital of Heidelberg is shown in Figure 4 as an example of the type of facility that is proposed for Australia. At this stage the proposed design for a combined proton carbon facility has a slightly different arrangements of the magnets in the accelerator system and the actual configuration of the delivery system to the various treatment rooms would be modified to suit the selected site.

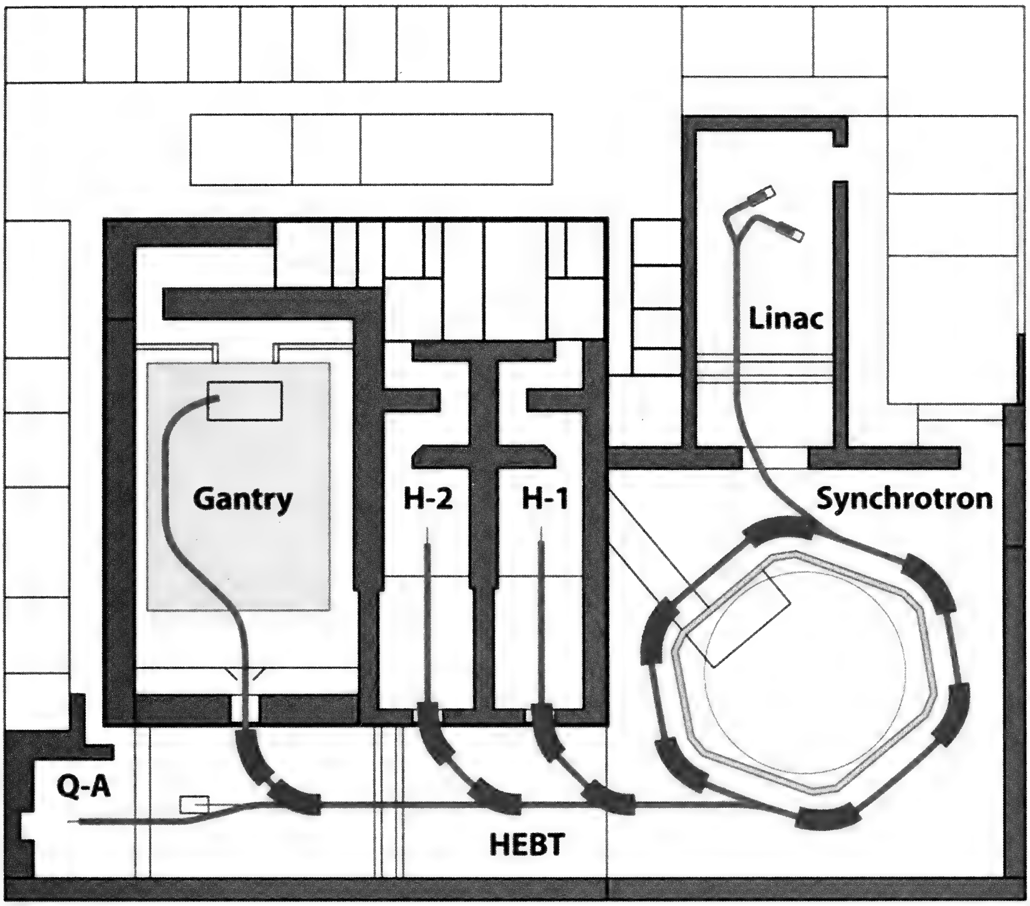

Figure 4: Layout of the Heidelberg Ion Therapy Facility

A preliminary assessment of the pros and cons of the alternative options is given in Tables 1- 4.

PROS	CONS
• Lowest cost option. • Low risk. • Short construction time.	• Slightly inferior performance relative to a synchrotron. • No flexibility. • Very limited research capability. • Very limited technology transfer. • Long term dependence on supplier organization.

Table 1 – Commercial Cyclotron – Protons only – Warm or superconducting

PROS	CONS
• Low cost . • Low risk.	• More control of beam than with a cyclotron. • Some flexibility but limited by the synchrotron. • Limited research capability. • Some technology transfer. • Independence from the supplier.

Table 2 – Commercial Synchrotron – Protons only

PROS	CONS
• Potentially lowest cost of all. • Greater flexibility. • Good technology transfer. • Improved research capability.	• Some risk. • Less options than carbon-proton machine.

Table 3 – Nationally Constructed Synchrotron – Protons only

Summary

A **commercial cyclotron facility** can be purchased from a number of international suppliers. There is limited risk in this operation. However the facility would have very limited value for research, a slightly lower therapy capability and the majority of the funds would be spent overseas. Technology generation in Australia would be at a minimum.

A **Nationally-Constructed High Performance Synchrotron** facility offers the optimum in performance, research and technology development. A high proportion of the funds would be spent in Australia. The physics design of such a facility has been completed and specialist international advisors have committed to providing support. However this is the highest cost facility.

A more modest synchrotron with proton beams only could be designed with limited effort. The transfer beamlines could be adapted with minimum effort from the designs already developed for the higher performance synchrotron.

The construction of the facility will in its own right introduce a great number of new technologies into Australia as has been seen with the construction of two pieces of scientific infrastructure, the OPAL research reactor and the Australian Synchrotron.

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Comparison of dorsal and pectoral fin denticles for grey nurse, great white, and six whaler sharks from east Australian waters

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Abstract

Escalating demand for shark fins poses a major threat to shark populations world-wide and the monitoring of shark catches can be very difficult when only the fins are present. Identifying a species of shark using only its fins can be enhanced by using the dermal denticles as they maintain their structural integrity irrespective of freezing or drying. In this study, scanning electron microscopy was used to examine various denticle characteristics including: the number and persistence of ridges and cusps, posterior edge appearance, dispersion and size (length and width) at three positions (anterior margin, centre and posterior margin) on the dorsal fin and dorsal surface of the pectoral fin of sharks caught in the coastal waters off New South Wales, Australia. Samples were obtained from commercial and recreational fishers, and the shark meshing programme. Catches included two threatened species – *Carcharias taurus* and *Carcharodon carcharias*, and six carcharhinid whalers – *Carcharhinus brachyurus, C. falciformis, C. leucas, C. limbatus, C. longimanus* and *C. obscurus*. Detailed examination revealed similarities and differences among sampling positions within a fin, between fin types, and among species. Patterns of change in denticle characteristics and size across the sampling positions provided an efficacious means of unequivocally identifying eight shark species. Future studies should evaluate field-based sampling of denticle characteristics as they may provide a cost-effective alternative to genetic techniques for identifying sharks and enable much needed data on the quantity and species composition of sharks harvested for their fins in local waters.

Keywords: elasmobranch, dermal denticle, Carcharhinidae, threatened species, taxonomy.

Introduction

The protein mining (*sensu* Field et al. 2009a) of the world's oceans via recognised fisheries and illegal, unreported and unregulated fishing (FAO 2007, Pitcher et al. 2002) has lead to declining fish populations and various ecosystem changes (Stevens et al. 2000, Pauly et al. 2005, Worm et al. 2006). There is irrefutable evidence of world-wide, declining shark populations (Baum et al. 2003, Myers & Worm 2003, Baum & Myers 2004, Field et al. 2009b). These declines are exacerbated by their relatively slow growth, late onset of sexual maturity, low fecundity and extended longevity which makes them extremely susceptible to over-fishing and many species require decades to recover (Smith et al. 1998, Cortés 2000, Mollet & Cailliet 2002). The primary causes of these declines are targeted shark fisheries (e.g. Walker 1998, Santana et al. 2009), by-catch in other fisheries (e.g. Marin et al. 1998, Campana et al. 2009) and the burgeoning shark-fin trade fuelled by booming Asian economies and increased personal wealth (Rose 1996, Clarke et al. 2007).

For many centuries shark fins have been a traditional component in Chinese banquets (Rose 1996) and the escalating demand has resulted in illegal harvesting (Shivji et al. 2005, Dulvy et al. 2008). Recent analyses of commercial fin-trade records (Clarke 2004, Clarke et al. 2006) have indicated that the shark catch documented in FAO databases has been substantially under-reported. It is likely that the wasteful shark-fining practices (comprising capture, fin removal and disposal at sea) have greatly contributed to the under-reporting of global shark catches. To redress this, some jurisdictions including Australia and parts of Central America now require that all shark carcasses are brought ashore prior to finning as this enhances species identification, the monitoring of catch, regulatory compliance and reduces waste (Dulvy et al. 2008).

The absence of the numerous morphological characteristics used with whole carcasses (e.g. Garrick 1982, Compagno 2002, Last & Stevens 2009) makes the identification of a shark from its fins alone substantially more difficult. While fin colour and shape have been used in studies of the Japanese longline fishery (Matsunaga et al. 1998, Nakano & Kitamura 1998), colouration can vary with fin size, and can be altered by post-mortem freezing and/or drying (Salini et al. 2007). The shape of fins can be similarly affected or be damaged with a subsequent loss of distinguishing characteristics. In contrast, a shark's dermal denticles maintain their structural integrity irrespective of freezing or drying and enable the species identification (Applegate 1967, Nakano & Kitamura 1998, Salini et al. 2007). For example, Tanaka et al. (2002) described the denticle characteristics of thirteen pelagic sharks from Japanese waters using scanning electron microscopy (SEM) and showed that specific characteristics could be used for species identification. Variation in denticle characteristics at different locations on a shark (e.g. fins versus the torso) has also been documented (e.g. Bagar & Thorson 1995, Salini et al. 2007) and can pose problems for species identification. Nevertheless, these are easily mitigated via rigorous experimental protocols and detailed descriptions of sampling location: information that has been notably absent in some previous studies (e.g. Matsunaga et al. 1998). In contrast, more recent studies (Shivji et al. 2002, Abercrombie et al. 2005, Clarke et al. 2007) have focussed on the development of complex genetic techniques for identifying a range of shark species from their fins and will be extremely valuable for legal proceedings. In processing the fins for human consumption, the skin is removed and the fins are soaked in bleach (Rose & McLoughlin 2001), making the use of denticles for identification impossible, and the extraction of DNA more difficult. In spite of this, the relative simplicity associated with using denticle characteristics, especially with the development of field-based techniques (e.g. digital macro-photography), will likely provide a very cost-effective, efficacious means of identifying sharks from their fins per se.

The shelf waters off New South Wales (NSW) Australia (Latitudes 28 – 37° S) support a diverse, predominantly temperate fish community that has formed the basis of numerous fisheries targeting invertebrates, bony fish and elasmobranchs. Sharks, in particular, have been commercially targeted and caught as by-catch in the Ocean Trap and Line, Ocean Trawl, Estuary General and Ocean Hauling fisheries (Pollard et al. 1996, Scandol et al. 2008, Macbeth et al. 2009) operating along the entire NSW coast. In contrast, recreational anglers have generally caught sharks when targeting bony fish (Henry & Lyle 2003), although some deliberate targeting has occurred, especially during gamefishing competitions (Stevens 1984, Pepperell 1992). Sharks have also been targeted by the shark meshing programme (SMP) operating off the bathing beaches from Newcastle to Wollongong (Reid & Krogh 1992,

Krogh 1994). The commercial and recreational fishing sectors and the SMP have also inadvertently caught two threatened shark species: the "critically endangered" grey nurse shark, *Carcharias taurus* Rafinesque, 1810 and the "vulnerable" great white shark, *Carcharodon carcharias* Linnaeus, 1758 (Krogh & Reid 1996, Otway et al. 2004, Bruce et al. 2006).

Under NSW legislation (Fisheries Management Act, 1994) it is illegal to fin a shark and then discard the carcass whilst at sea, but this practice continues as fisheries compliance officers still confiscate illegally harvested shark-fins. In the absence of a field-based technique for identifying NSW sharks from their fins per se, offences relating to the two threatened sharks may be overlooked. Additionally, the catches of several other sharks included on the IUCN Red List (Cavanagh et al. 2003), but not currently recognised under Australian legislation are unlikely to be quantified. Hence, the twofold objectives of this study were to document the various characteristics of denticles sampled from first dorsal and pectoral fins of sharks and then examine whether the denticle characteristics could be used to identify and discriminate among the range of shark species caught.

Methods

Field Sampling

Sharks were sampled from the SMP and catch of commercial and recreational fishers in NSW waters from January 1995 to March 2008. Sharks were identified using standard taxonomic methods (Garrick 1982, Compagno 2002, Last & Stevens 2009) and the total length (TL) was measured to the nearest centimetre with the caudal fin in the depressed position (Francis 2006). The first dorsal and pectoral fins were then removed by cutting the torso anteriorly from under the free rear tip and inner margin, passing below the cartilaginous elements to a point 5 cm anterior to the origin of the fin. The entire, undamaged fins were then placed in labelled plastic bags and stored in a chest freezer at -200 C until processed.

Skin Sampling and Scanning Electron Microscopy (SEM)

Preliminary sampling of dorsal fins showed that there were no differences in denticle morphology on either side of the fin, thus the side of the fin sampled was chosen at random. In contrast, all pectoral fins were sampled on the dorsal surface. Skin samples (≈ 50 x 20 mm) were removed, from three sampling positions (anterior margin, centre and posterior margin – Fig. 1a) from a thawed fin using a scalpel and forceps.

Each skin sample was subjected to a standardised cleaning and desiccation process prior to detailed examination using SEM. Briefly, skin samples were placed in a 95% ethanol bath in a Branson ultrasonic cleaner which was run for three minutes. The ethanol was then replaced and the process repeated. Finally, each sample was rinsed with ethanol, fastened (using clips) to a rigid, plastic board to prevent buckling and placed in a desiccator to dry. After 5 days, all samples were dry and each skin sample was cut into three replicate sub-samples (≈ 15 x 15 mm and placed on 25 mm diameter aluminium stubs using carbon paint to ensure a conductive track. A 10-20 nm gold coat was then applied using a SPI sputter coating unit. Each sample was then examined on a Philips XL Series – XL30 scanning electron microscope fitted with a tungsten electron gun and images obtained at 15kv with 200x and 400x magnification. All SEM images were orientated so that the anterior-posterior axes of the denticles aligned vertically with the anterior edge at the top.

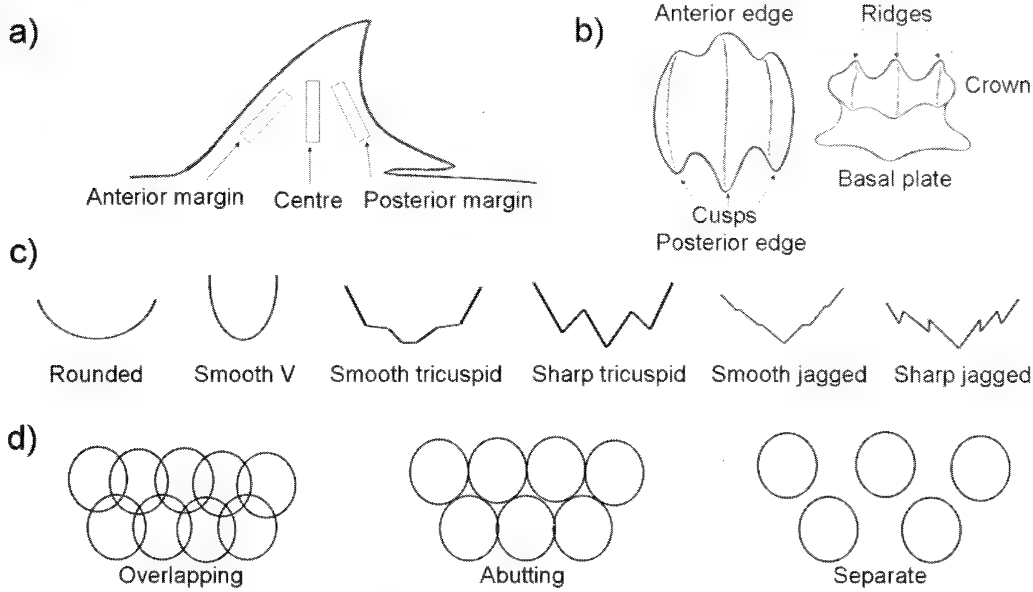

Figure 1. Sampling protocol and denticle characteristics used to describe (a) the 3 sampling locations from the first dorsal and pectoral fin anterior margin, centre and posterior margin (b) Characteristics of a typical denticle as viewed from above (left) and from the side (right) (c) Terminology used to describe the shape of the posterior edge of denticles (d) The definitions of denticle distribution types.

Denticle Descriptions

Descriptions of the denticles from the three sampling positions on each of the first dorsal and pectoral fins for each shark species were compiled using common features and consistent terminology. The crown of the denticle may be smooth, have depressions, or more commonly have a surface with one or more ridges aligned in an anterior – posterior direction (Fig. 1b). The number of ridges/denticle was recorded and the ridges described as they may run the entire length or dissipate towards the posterior edge of the denticle. Commonly, a denticle's anterior edge is rounded while the posterior edge is indented. Thus, the shape of a denticle's posterior edge was described, its appearance (distinct or indistinct) noted and number of cusps recorded (Fig. 1c). Finally, the dispersion of the denticles was classified into one of three types (Fig. 1d). Overlapping dispersion comprised very dense, regularly-spaced denticles that overlapped along the anterior, posterior and lateral edges. Abutting dispersion comprised dense, regularly-spaced denticles with contact, but no overlap along the edges. Separated dispersion comprised regularly-spaced denticles with no overlapping edges and an obvious space between surrounding denticles.

Statistical Analyses

Length and width of denticles in SEM images were measured to the nearest 0.5 µm using Grab It! XP Software. Replicate measurements were obtained from each of four, randomly-chosen denticles at the three sampling positions on the first dorsal and pectoral fins. To examine whether multivariate statistical analyses could differentiate species using either the first dorsal or pectoral fins, PRIMER version 6.1.9 was used to produce two-dimensional MDS ordination plots following square root transformation of replicate (length & width)

measurements and the calculation of Euclidean distance. A one-way analysis of similarity (ANOSIM) for each fin was used to test for significant differences among species.

Results

Numerous sharks comprising nineteen species from seven families were obtained from the combined catches of the SMP, commercial and recreational fisheries along the entire NSW coast. Greater numbers of individuals and species were obtained between Coffs Harbour and Wollongong, and this was associated with increased sampling effort in this region (Fig. 2).

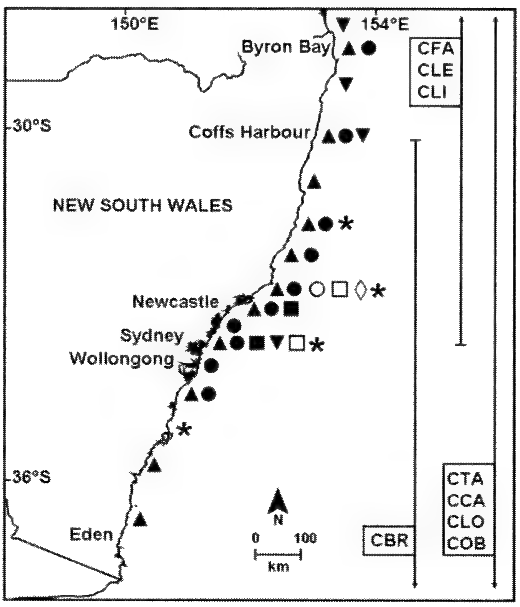

Figure 2. Map showing with geographic range (line) and capture locations (symbol) for Carcharias taurus (CTA, ▲), Carcharodon carcharias (CCA, •), Carcharhinus brachyurus (CBR, ■), C. falciformis (CFA, ○), C. leucas (CLE, ▼), C. limbatus (CLI, □), C. longimanus (CLO, ◊), and C. obscurus (COB, *) *along the coast of New South Wales, Australia.*

While the combined catch included eleven species of carcharhinid whaler, only six species (*Carcharhinus brachyurus, C. falciformis, C. leucas, C. limbatus, C. longimanus* and *C. obscurus*, pooled n = 30) together with *Carcharias taurus* (n = 31) and *Carcharodon carcharias* (n = 17) are examined in this study. Descriptions of the denticles in the remaining species will be provided in subsequent papers.

Furthermore, a sexually-mature, 272 cm TL, female *C. taurus* that had survived finning (i.e., dorsal, pectoral & lower caudal fins absent) was also examined following its accidental capture in June 2002 on a demersal setline off the NSW south coast.

Comparisons Between Fins and Among Fin Positions

Denticle samples used in this study were obtained from individuals 111 to 450 cm TL. Detailed examination of the eight species clearly showed that the various denticle characteristics did not differ between the sexes. The SEM images of the denticles (Figs. 3–5) and their various characteristics (Tables 1–3) highlight the similarities and differences among sampling positions within a fin, between fin types, and among species.

The denticles from the first dorsal and pectoral fins of *Carcharias taurus* (Fig. 3) were shield-shaped and very similar. Denticle size (length & width) and dispersion differed among the three sampling positions (anterior margin, central and posterior margin) with smaller, separated denticles at the posterior margin of the dorsal fin (Tables 1 & 3). In contrast, the pectoral fin denticles were larger and abutting at the anterior margin compared to the remaining positions on the fin (Tables 1 & 3).

The denticles from the first dorsal and pectoral fins of *Carcharodon carcharias* were ellipsoidal in shape and had similar features (Fig. 3). Denticles on the dorsal fin differed among sampling positions with those at the anterior

margin exhibiting no cusps, a smooth posterior edge and larger size (Tables 1 & 3). A similar pattern of difference was evident on the pectoral fin denticles which had no cusps, a rounded posterior edge and larger size at the anterior margin (Tables 1 & 3).

The denticles from the first dorsal and pectoral fins of *Carcharhinus brachyurus* (Figs. 4 & 5) were diamond-shaped, similar in some features and differed among sampling positions (Tables 2 & 3). Denticles at the posterior margin of the dorsal fin had continuous ridges, five cusps and a smooth, jagged posterior edge. In contrast, denticles at the anterior margin of the pectoral fin exhibited the greatest difference with dissipating ridges, no cusps, and a smooth V posterior edge.

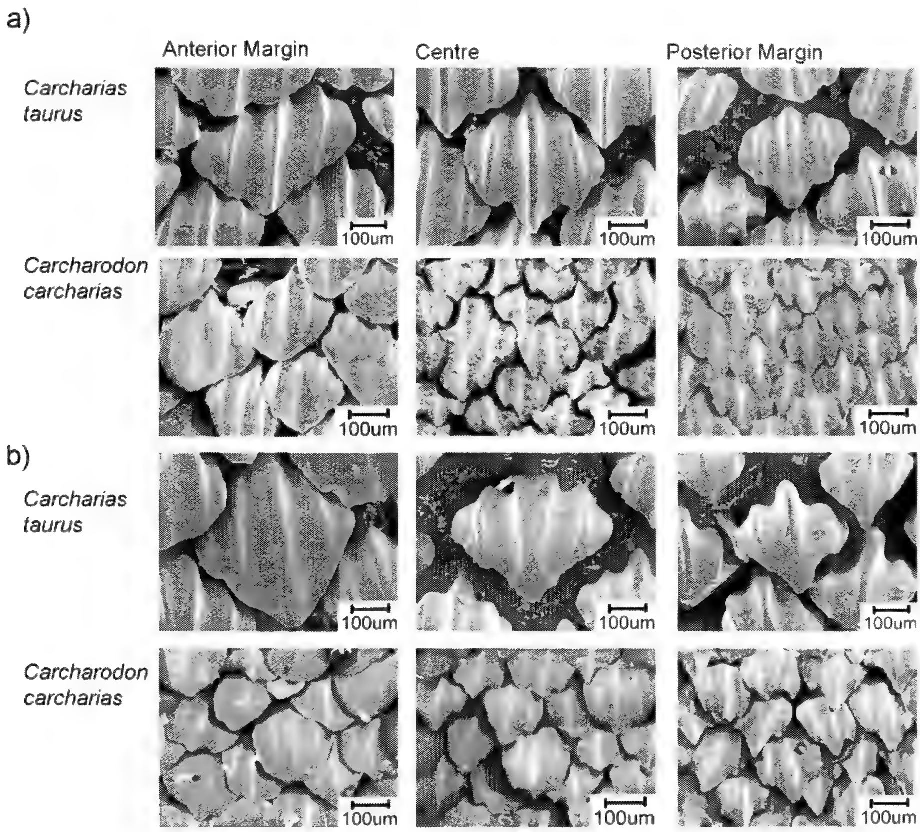

Figure 3. Scanning electron micrographs of denticles from the anterior margin, centre and posterior margin of (a) the first dorsal fin and (b) the dorsal surface of the pectoral fin of Carcharias taurus *(251 cm TL) and* Carcharodon carcharias *(209 cm TL).*

Denticles from the first dorsal and pectoral fins of *C. falciformis* (Figs. 4 & 5) were diamond-shaped with differences on the dorsal fin arising via a smooth V posterior edge and abutting denticles at the anterior margin (Table 2). Differences on the pectoral fin were evident through the varying shapes of the posterior edge across the three sampling positions and

overlapping denticles at the posterior margin (Table 2).

Denticles from the first dorsal and pectoral fins of *C. leucas* (Figs. 4 & 5) were diamond-shaped, large and showed various similarities (Tables 2 & 3). Denticles on the dorsal fins differed among sampling positions with those at the anterior margin exhibiting dissipating ridges, no cusps and a smooth V posterior edge. Smaller denticles were also present at the posterior margin. A similar pattern of difference was evident on the pectoral fins except that abutting denticles occurred at the anterior margin and their size did not differ among sampling positions.

Denticles from the first dorsal and pectoral fins of *C. limbatus* (Figs. 4 & 5) were diamond-shaped and very similar overall (Tables 2 & 3). Smaller denticles at anterior margin were the only difference apparent on the first dorsal fin. Differences on the pectoral fin were manifest via larger denticles at the anterior margin together with distinct cusps and a sharp jagged posterior edge at the posterior margin.

Denticles from the first dorsal and pectoral fins of *C. longimanus* (Figs. 4 & 5) were diamond-shaped and exhibited many similarities. Differences on the dorsal fin were confined to the anterior margin where denticles were abutting and had dissipating ridges (Table 2). In contrast, differences on the pectoral fin occurred at the posterior margin with denticles possessing distinct cusps and a sharp, jagged posterior edge (Table 2).

Denticles from the first dorsal and pectoral fins of *C. obscurus* (Figs. 4 & 5) were diamond-shaped with some variation among fin positions (Tables 2 & 3). The denticles at the anterior margin of the dorsal fin had no ridges and cusps, and a smooth V posterior edge and differed from those at the other sampling positions. Similarly, the denticles from the anterior margin of the pectoral fin were distinctive because of dissipating ridges, no cusps and a smooth V posterior edge.

Species	**Position**	**Ridges** (No., Persistence)	**Cusps** (No., Form)	**Posterior edge**	**Dispersion**
First Dorsal Fin					
Carcharias	AM	3, Continuous	3, Indistinct	Smooth tricuspid	Abutting
taurus	C	3, Continuous	3, Indistinct	Smooth tricuspid	Abutting
	PM	3, Continuous	3, Indistinct	Smooth tricuspid	Separated
Carcharodon	AM	3, Continuous	0, Absent	Smooth V	Overlapping
carcharias	C	3, Continuous	3, Distinct	Sharp tricuspid	Overlapping
	PM	3, Continuous	3, Distinct	Sharp tricuspid	Overlapping
Pectoral Fin					
Carcharias	AM	3, Continuous	3, Indistinct	Smooth tricuspid	Abutting
taurus	C	3, Continuous	3, Indistinct	Smooth tricuspid	Separated
	PM	3, Continuous	3, Indistinct	Smooth tricuspid	Separated
Carcharodon	AM	3, Continuous	0, Absent	Rounded	Overlapping
carcharias	C	3, Continuous	3, Distinct	Sharp tricuspid	Overlapping
	PM	3, Continuous	3, Distinct	Sharp tricuspid	Overlapping

Table 1. Denticle characteristics for the anterior margin (AM), centre (C) and posterior margin (PM) of the first dorsal fin and dorsal surface of the pectoral fin of Carcharias taurus (251 cm TL) and Carcharodon carcharias (209 cm TL).

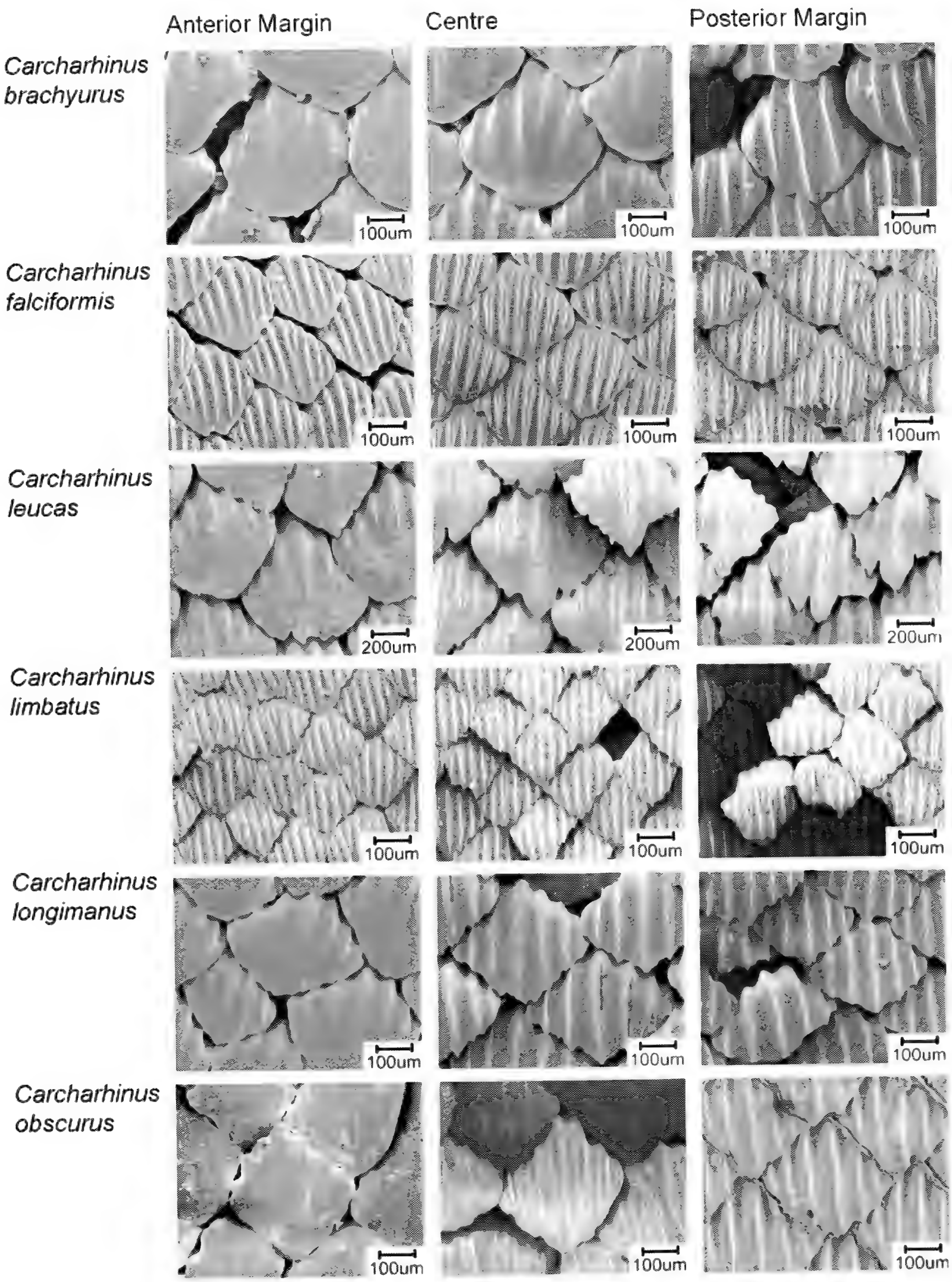

Figure 4. Scanning electron micrographs of denticles from the anterior margin, centre and posterior margin of the first dorsal fin from Carcharhinus brachyurus *(271 cm TL),* C. falciformis *(264 cm TL),* C. leucas *(239 cm TL),* C. limbatus *(265 cm TL),* C. longimanus *(178 cm TL) and* C. obscurus *(265 cm TL).*

Species	**Position**	**Ridges** (No., Persistence)	**Cusps** (No., Form)	**Posterior edge**	**Dispersion**
First Dorsal Fin					
Carcharhinus brachyurus	AM	5, Dissipate	0, Absent	Rounded	Overlapping
	C	5, Dissipate	0, Absent	Rounded	Overlapping
	PM	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
Carcharhinus falciformis	AM	5-7, Continuous	0, Absent	Smooth V	Abutting
	C	5-7, Continuous	0, Absent	Rounded	Overlapping
	PM	5-7, Continuous	0, Absent	Rounded	Overlapping
Carcharhinus leucas	AM	5-7, Dissipate	0, Absent	Smooth V	Overlapping
	C	5-7, Continuous	5, Distinct	Sharp jagged	Overlapping
	PM	5-7, Continuous	5, Distinct	Sharp jagged	Overlapping
Carcharhinus limbatus	AM	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
	C	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
	PM	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
Carcharhinus longimanus	AM	5, Dissipate	5, Indistinct	Smooth jagged	Abutting
	C	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
	PM	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
Carcharhinus obscurus	AM	0, Absent	0, Absent	Smooth V	Abutting
	C	5, Continuous	5, Indistinct	Smooth jagged	Abutting
	PM	5, Continuous	5, Indistinct	Smooth jagged	Abutting
Pectoral Fin					
Carcharhinus brachyurus	AM	5, Dissipate	0, Absent	Smooth V	Abutting
	C	5, Continuous	5, Indistinct	Smooth jagged	Abutting
	PM	5, Continuous	5, Indistinct	Smooth jagged	Overlapping
Carcharhinus falciformis	AM	5-7, Continuous	0, Absent	Rounded	Abutting
	C	5-7, Continuous	0, Absent	Smooth jagged	Abutting
	PM	5-7, Continuous	0, Absent	Smooth V	Overlapping
Carcharhinus leucas	AM	5-7, Dissipate	0, Absent	Smooth V	Abutting
	C	5-7, Continuous	5, Distinct	Sharp jagged	Overlapping
	PM	5-7, Continuous	5, Distinct	Sharp jagged	Overlapping
Carcharhinus limbatus	AM	5-6, Continuous	5-6, Indistinct	Smooth jagged	Overlapping
	C	5-6, Continuous	5-6, Indistinct	Smooth jagged	Overlapping
	PM	5-6, Continuous	5-6, Distinct	Sharp jagged	Overlapping
Carcharhinus longimanus	AM	5, Continuous	5, Indistinct	Smooth jagged	Abutting
	C	5, Continuous	5, Indistinct	Smooth jagged	Abutting
	PM	5, Continuous	5, Distinct	Sharp jagged	Abutting
Carcharhinus obscurus	AM	5, Dissipate	0, Absent	Smooth V	Abutting
	C	5, Continuous	5, Indistinct	Smooth jagged	Abutting
	PM	5, Continuous	5, Indistinct	Smooth jagged	Abutting

Table 2. Denticle characteristics of the anterior margin (AM), centre (C) and posterior margin (PM) from first dorsal fin and dorsal surface of the pectoral fins of Carcharhinus brachyurus *(271 cm TL), C. falciformis (264 cm TL),* C. leucas *(239 cm TL),* C. limbatus *(265 cm TL),* C. longimanus *(178 cm TL) and* C. obscurus *(265 cm TL).*

Species	Position	Dorsal fin		Pectoral fin	
		Length (µm)	Width (µm)	Length (µm)	Width (µm)
Carcharias taurus	AM	301 (± 27)	298 (± 30)	389 (± 10)	386 (± 38)
	C	302 (± 12)	310 (± 12)	274 (± 7)	306 (± 9)
	PM	246 (± 7)	252 (± 13)	284 (± 13)	262 (± 12)
Carcharodon carcharias	AM	314 (± 18)	293 (± 14)	242 (± 12)	236 (± 10)
	C	216 (± 5)	192 (± 6)	233 (± 18)	191 (± 8)
	PM	230 (± 8)	205 (± 4)	225 (± 4)	195 (± 5)
Carcharhinus brachyurus	AM	403 (± 23)	439 (± 22)	473 (± 16)	427 (± 22)
	C	453 (± 7)	410 (± 13)	446 (± 17)	391 (± 18)
	PM	411 (± 24)	403 (± 8)	463 (± 14)	354 (± 15)
Carcharhinus falciformis	AM	252 (± 21)	270 (± 31)	342 (± 5)	391 (± 9)
	C	277 (± 4)	340 (± 8)	318 (± 8)	395 (± 13)
	PM	274 (± 4)	327 (± 14)	337 (± 13)	382 (± 10)
Carcharhinus leucas	AM	752 (± 12)	762 (± 15)	746 (± 13)	751 (± 22)
	C	738 (± 20)	783 (± 28)	695 (± 14)	749 (± 20)
	PM	654 (± 25)	672 (± 14)	721 (± 7)	652 (± 21)
Carcharhinus limbatus	AM	189 (± 7)	194 (± 7)	303 (± 21)	278 (± 10)
	C	225 (± 8)	204 (± 6)	252 (± 5)	255 (± 16)
	PM	222 (± 6)	237 (± 5)	225 (± 4)	256 (± 13)
Carcharhinus longimanus	AM	330 (± 7)	385 (± 13)	307 (± 9)	377 (± 5)
	C	333 (± 11)	423 (± 6)	358 (± 8)	422 (± 7)
	PM	270 (± 10)	371 (± 21)	262 (± 10)	348 (± 11)
Carcharhinus obscurus	AM	401 (± 21)	398 (± 16)	477 (± 18)	437 (± 16)
	C	399 (± 19)	451 (± 23)	453 (± 16)	463 (± 19)
	PM	360 (± 18)	386 (± 17)	485 (± 17)	466 (± 18)

Table 3. Mean (± SE) length and width of denticles sampled from the anterior margin (AM), centre (C) and posterior margin (PM) of the first dorsal fin and dorsal surface of the pectoral fin of Carcharias taurus, Carcharodon carcharias, Carcharhinus brachyurus, C. falciformis, C. leucas, C. limbatus, C. longimanus, *and* C. obscurus.

Comparisons Among Species

The two threatened species, *Carcharias taurus* and *Carcharodon carcharias,* had three continuous ridges on the denticles from all sampling positions on the first dorsal and pectoral fins (Table 1). This single characteristic distinguished both species from the six carcharhinid whalers which had at least five ridges on the denticles from the centre and posterior margin of the first dorsal and pectoral fins (Table 2). *C. taurus* had three cusps on the denticles from all sampling positions on the first dorsal and pectoral fins, whereas *C. carcharias* had no cusps present on the denticles at the anterior margin of both fins (Table 1). This pattern of difference could be used to distinguish the species.

The pattern of difference in the denticle characteristics across the sampling positions could also be used to distinguish the six carcharhinid whalers. For example, the denticles on the dorsal fins of *Carcharhinus brachyurus* and *C. falciformis* exhibited distinct

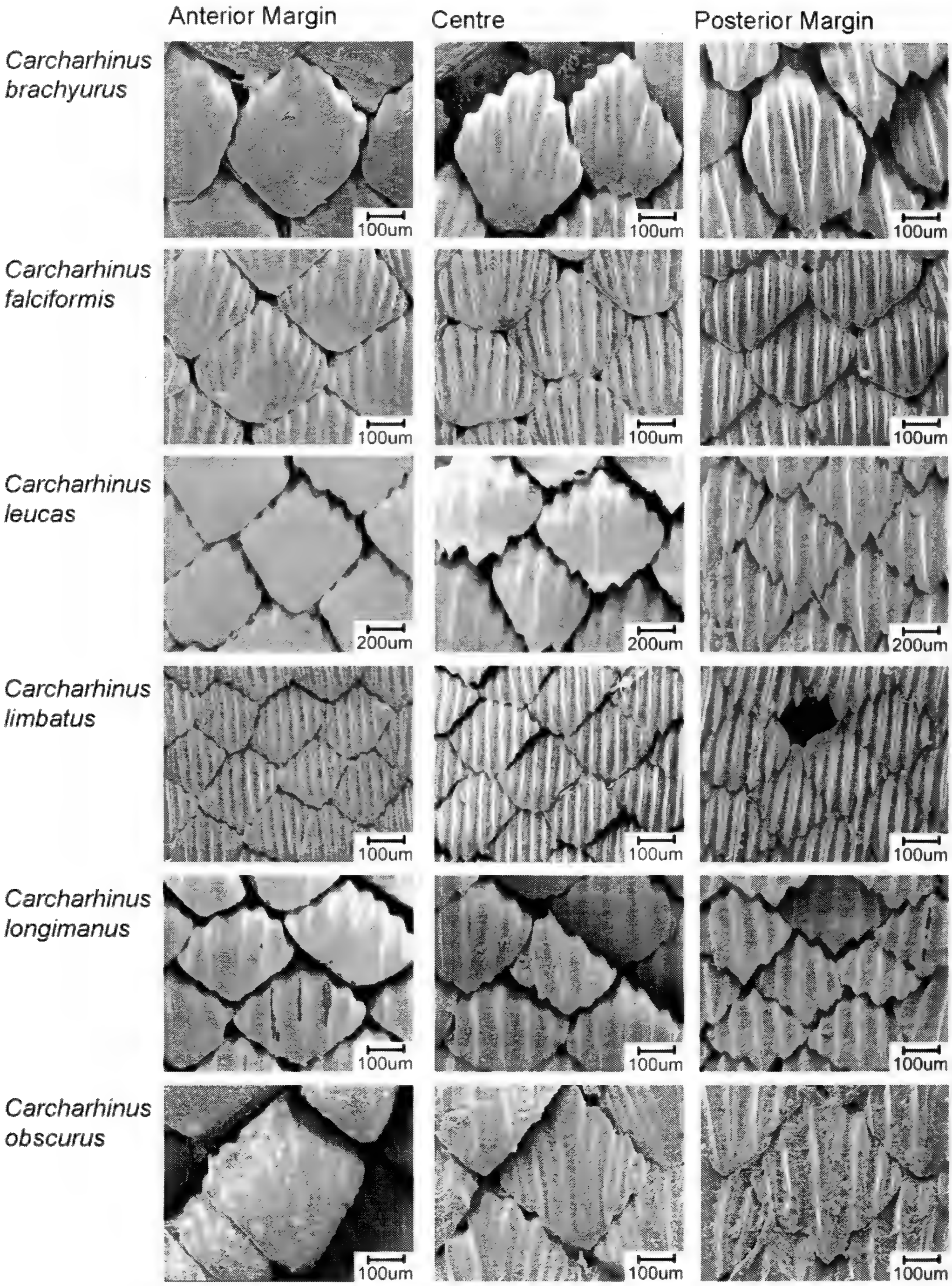

Figure 5. Scanning electron micrographs of denticles from the anterior margin, centre and posterior margin of the dorsal surface of the pectoral fin from Carcharhinus brachyurus *(271 cm TL)*, C. falciformis *(264 cm TL)*, C. leucas *(239 cm TL)*, C. limbatus *(265 cm TL)*, C. longimanus *(178 cm TL), and* C. obscurus *(265 cm TL)*.

patterns of difference across the fin. No ridges were present on denticles from the anterior margin in *C. obscurus*, whereas no cusps were present on denticles from the central region in *C. brachyurus* (Table 2). The pectoral fins also showed distinct patterns of difference among species. For example, there were no cusps on denticles across the fins of *C. falciformis*, whereas five to six cusps were present at all sampling positions in *C. limbatus* (Table 2).

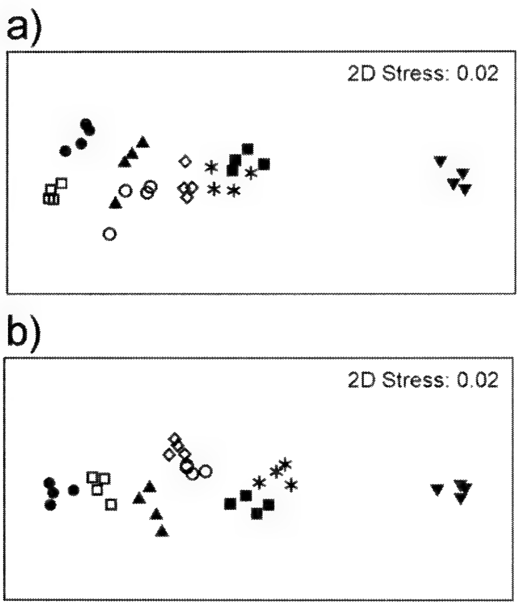

Figure 6. MDS ordination plots of denticle lengths and widths from the anterior margin, centre and posterior margin (n = 4 replicates) for (a) the first dorsal fin and (b) the dorsal surface of the pectoral fin from Carcharias taurus (▲), Carcharodon carcharias (●), Carcharhinus brachyurus (■), C. falciformis (○), C. leucas (▼), C. limbatus (□), C. longimanus (◊), *and* C. obscurus (*).

The size (length & width) of denticles from the first dorsal and pectoral fins also showed distinct patterns of difference across the three sampling positions (Table 3) and suggested that size of denticles could be used to distinguish among species. The size of denticles from the first dorsal fin (Fig. 6a) differed among species (ANOSIM, Global $R = 0.944$, $P < 0.001$) and, all except two, pairwise tests were significant (pairwise $R = 0.771 – 1.000$, $P = 0.029$). The pairwise tests could not distinguish the differences in denticle-size between *Carcharias taurus* and *Carcharhinus falciformis* (pairwise $R = 0.188$, $P = 0.117$), and *C. brachyurus* and *C. obscurus* (pairwise $R = 0.365$, $P = 0.057$). The size of denticles from the pectoral fin (Fig. 6b) also differed among species (ANOSIM, Global $R = 0.970$, $P < 0.001$) and all pairwise tests were significant (pairwise $R = 0.802 – 1.000$, $P \leq 0.029$) indicating clear separation of the eight sharks species.

Discussion

Varying numbers of sharks, comprising the eight species provided representative samples for detailed examination of the denticles from the first dorsal and pectoral fins. The sharks were caught at various locations along the entire NSW coast and this reflected their established geographic ranges (Stevens 1984, Last & Stevens 2009, Otway & Ellis 2011). The incidental capture of *Carcharias taurus* and *Carcharodon carcharias* occurred along the entire NSW coast and was consistent with other studies of the SMP (Krogh & Reid 1996, Reid et al. 2011), commercial fisheries (Pollard et al. 1996, Macbeth et al. 2009) and the recreational fishing sector (Pepperell 1992, Otway et al. 2004).

Comparisons Among Species

The overall appearances of the denticles, irrespective of sampling position, were in general agreement with earlier descriptions (Garrick 1982, Bargar & Thorson 1995, Matsunaga et al. 1998, Nakano & Kitamura 1998). While some studies (e.g. Garrick 1960, Applegate 1967) have documented size-related differences in denticle characteristics particularly with small juveniles, there were no marked

differences in denticle size and characteristics between the sexes and among individuals >150 cm TL. This result was in agreement with Salini et al. (2007) who showed that there were limited changes in denticle characteristics after a species-specific TL was attained (e.g. *C. limbatus* >150 cm TL). However, the reduced numbers of neonates and juveniles (0–2 years) examined in this study (particularly with whalers) prevented an extensive evaluation of possible size-related differences in denticle characteristics in very small sharks. Quantifying the degree of variation and its implications for species identification in young individuals will require additional sampling in the future.

Previous studies (e.g. Bagar & Thorson 1995, Garrick 1982 , Salini et al. 2007) have shown denticle characteristics can vary with location on the fins and/or torso. Variation in denticle characteristics across the fins was also clearly evident in this study. Despite this, it was still possible to distinguish species through either clear differences in denticle characteristics from one or all of the sampling positions. The number of denticle ridges was the most obvious character that distinguished groups of similar species. For example, the carcharhinid whalers had five to seven ridges on denticles from at least one sampling position, whereas *Carcharias taurus* and *Carcharodon carcharias* had only three ridges on the denticles from each sampling position.

Patterns of change in denticle characteristics across the sampling positions could also be used to discriminate species or groups of similar species. For example, the dispersion of dorsal fin denticles across the three sampling positions separated three distinct groups within the carcharhinid whalers. Three species (*C. brachyurus*, *C. leucas* and *C. limbatus*) displayed no change in the overlapping denticle dispersion across sampling positions. In contrast, the dispersion of denticles changed from abutting at the anterior margin to overlapping at the centre and posterior margin in *C. falciformis* and *C. longimanus*. Finally, *C. obscurus* had abutting denticle dispersion which did not change across sampling positions. With this in mind, future studies should quantify denticle characteristics from several sampling positions on a fin as this will enable patterns of change (or no change) in denticle characteristics for augmenting the identification of shark species.

The use of denticle size (i.e., length and width) as a method for differentiating species has not been explored in previous studies. Similar to the denticle characteristics, there were distinct patterns of change in denticle size across the three sampling positions. The size of denticles from the first dorsal fin separated all species except *Carcharias taurus* and Carcharhinus falciformis, and *Carcharhinus brachyurus* and Carcharhinus obscurus, respectively. However, the size of denticles from the pectoral fin unequivocally separated all eight species. Combining denticle size with the other denticle characteristics provides an efficacious approach to species identification, and a method for enhancing taxonomic keys developed previously (e.g. Garrick 1982, Compagno 2002, Last & Stevens 2009). For example, if only denticle size from the dorsal fins was used, the additional denticle characteristics and dispersion provided a method of unequivocally separating species.

Large-Scale Geographic Comparisons

The denticle characteristics at the anterior margin and centre of the first dorsal fin of *C. leucas* from NSW waters were entirely consistent with those described from Costa Rica (Bagar & Thorson 1995). Similarly, the denticle characteristics from the centre of the first dorsal fins of *Carcharhinus longimanus*, *C. falciformis* and *C. obscurus* from NSW waters were consistent with those observed from these species in Japanese waters (Tanaka et al. 2002). While the precise sampling details have been provided in several studies (e.g. Dingerkus & Koestler 1986,

Raschi & Tabit 1992, Mojetta 1997), others have not described exactly where, on the fins or torso, the denticles were obtained. For example, the specific sampling location on the first dorsal fin of Carcharhinus longimanus was not provided by Matsunaga et al. (1998) and while the denticle characteristics were similar to those described here, at least two different conclusions could be drawn. If Matsunaga et al. (1998) sampled the denticles from the centre or posterior margin of the fin, the denticles would be similar suggesting no large-scale geographic variation. Alternatively, if Matsunaga et al. (1998) sampled the denticles from the anterior margin of the first dorsal fin, then differences would have been evident and attributed to large-scale geographic variation.

More generally, the absence of detailed sampling information has lessened the number of large-scale geographic comparisons and reduced the efficacy of using denticle characteristics in shark taxonomy (e.g. Garrick 1982). To redress this, future studies should describe precisely where the denticles are sampled as this will enable unconfounded comparisons of denticle characteristics within and among species, and between geographic regions.

Management Implications for the Shark-Fin Trade

With the ever-increasing demand for shark fins, the denticle characteristics documented in this study provide an alternative to genetic techniques (Shivji et al. 2002, Abercrombie et al. 2005, Clarke et al. 2007) for quantifying the species composition and quantities of sharks harvested for their fins in NSW waters.

Moreover, with the continuing incidental capture of *Carcharias taurus* and *Carcharodon carcharias* by the SMP, commercial and recreational fishers documented in this and other recent studies (Bruce et al. 2006, Macbeth et al. 2009, Otway & Ellis 2011, Reid et al. 2011), it is likely that the fins of these threatened species will find their way, albeit illegally, into the shark-fin trade. The denticle characteristics of *Carcharias taurus* and *Carcharodon carcharias* will permit an unequivocal, cost-effective method for detecting the presence of both species within the domestic (Rose & McLoughlin 2001, Lack & Sant 2006) and international (Rose 1996, Clarke 2004, Clarke et al. 2006) shark-fin trade and enable their illegal catch in NSW waters and elsewhere to be quantified.

Additionally, the populations of *Carcharhinus brachyurus*, *C. leucas*, *C. limbatus*, and *C. obscurus* are recognised as near threatened globally, whereas *C. longimanus* is recognised as globally threatened (i.e., Vulnerable) on the IUCN Red List (Cavanagh et al. 2003, Dulvy et al. 2008). The denticle characteristics of these species will also permit their identification and catches to be quantified.

Conclusion

Replicated sampling of various denticle characteristics from the three sampling positions on the first dorsal and pectoral fins of sharks of varying TL provided an efficacious means of unequivocally identifying eight shark species including the critically endangered *Carcharias taurus* and vulnerable *Carcharodon carcharias.* When sampling denticles, it is imperative that future studies ensure that the sampling locations (on the fins or torso) are adequately described to permit unconfounded comparisons of denticle characteristics within and among species, and over large geographic scales.

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The accelerating universe

A new view of the universe

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Abstract

Brian Schmidt was the leader of one of the two supernova search teams that discovered the universe is accelerating. His discovery was named Science Magazine's breakthrough of the year for 1998 and in 2011 he was awarded the Nobel Prize for Physics, along with Saul Perlmutter (University of California, Berkeley) and Adam Riess (John Hopkins University). He is a Fellow of the Australian Academy of Science and of the US National Academy of Sciences. He has made significant contributions in observational cosmology, supernovae, gamma ray bursts and all-sky surveys. This paper is based on an interview with him. It traces the trajectory that led Brian Schmidt to the accelerating universe and other achievements in astronomy.

Keywords: accelerating universe, dark energy, dark matter, Hubble constant, supernovae.

Introduction

From Missoula, Montana to Alaska, to Arizona, to Boston to Australia and the accelerating universe! Incredible as it sounds this is the long, arduous and exciting journey that Schmidt travelled over the first thirty-one years of his life. It was a life full of ups and downs. As a young boy he had already got a taste of moving from one place to another as his parents followed their careers and academic pursuits. So this movement from one place to another was inbuilt into his psyche. In some ways it was a traumatic experience for a growing lad but he seemed to have taken the changes in his stride as he made new friends and lost old ones and acclimatised himself to new places and environments.

Born in the small country town of Missoula, Montana in the Rockies in the northern part of the United States, he was very close to his young upwardly-mobile parents. As a young boy he acquired the protestant work ethic from his parents. From his father, a fisheries biologist he saw "the whole academic stream

and it quite appealed to me", he said. He also learnt the basic scientific skills of observation and experiment from him. "My mother", he said, "did a Master's degree in social sciences and I guess she showed me that there is a bunch of skills that she used in her jobs which are important as a scientist, which I think has made me a better scientist than I would have been otherwise". It is perhaps his mother's influence that has made him an excellent communicator of scientific ideas and an interesting and lively speaker for astronomy and science.

He did not attend posh private schools but spent his entire school life in government schools which in some cases had very good and highly motivated teachers. When he was fourteen his parents moved to Alaska. He attended Bartlett High School which according to Schmidt, "was a superb school. The teachers there were funded by Alaskan oil money and so

I had four teachers that had PhDs at high school and, you know, going to university was quite a step down and that's extremely unusual". He came under the influence of some very good science teachers who challenged him. But they were a little concerned that he wanted to do physics because many of their best students went out and failed physics. "And their view was that I wasn't the best they ever seen and I was going to fail. I think I probably surprised them how well I did".

From Arizona to Harvard

From Alaska he went to the University of Arizona in Tucson to do his undergraduate studies. Why to Arizona, when he could have gone to the University of Washington which was closer to home or the University of California? The University of California, he said, "was too expensive and hard to get into". He is not sure why he chose Arizona. "And to this day, I still ask myself, why did I go to the University of Arizona?" Although at the time he applied to study at the University of Arizona, he was not aware of the poor reputation of the Physics Department. However, he was aware that the astronomy department had a good reputation. After all Bart Bok (a former Director of the Mount Stromlo Observatory in Canberra) was an excellent representative of the astronomy department at that University. He spent most of his undergraduate years working long hours on his studies. "Spending almost sixty to seventy hours a week working on his studies", he said. Apart from the physics classes, he attended "a lot of astronomy classes and I had a good teacher there. Thomas Swihart". The academic staff were supportive and according to him, "they set me up to do a research project which I got embedded in with a guy by the name of John McGraw and interestingly enough, one of the things I got involved in doing was looking for supernovae". Some of the astronomers at the time he was there he recalls were Peter Strittmatter, Simon White, Rob Kennicutt, Dave Arnett, Craig Hogan, Jim Leibert, and Frank Low. Leibert was working on white dwarfs while Low was carrying out his well known studies in infrared astronomy.

On completing his undergraduate degree he had to decide where to go for his PhD studies. He could have gone to the University of California Santa Cruz where Sandy Faber, Mike Bolte, Stan Woosley, George Blumenthal, Peter Bodenheimer and David Koo were extremely active in studies that interested him but instead he chose to go Harvard University where Robert (Bob) Kirshner was actively engaged in research on supernovae. His decision to go to Harvard was made when he attended the first Marc Aaronson Memorial Lecture given by Kirshner at the University of Arizona. Marc Aaronson (a close collaborator of Jeremy Mould, a former Director of the Mount Stromlo Observatory and now of the National Optical Astronomy Observatory in Tucson) was killed in a freak telescope accident. According to Schmidt, he said to Kirshner, "I'll make you a deal. You let me be your student, allow me to work on supernovae and I'll come to Harvard because I have to make a decision. He replied, "Okay it sounds good". Once there he was not very keen on the supernova topics that Kirshner was suggesting. So he came up with his own idea for his PhD thesis. He informed Kirshner that he would like to measure the Hubble constant using supernovae, not just any supernovae but SN II. Unlike Supernovae Ia which are thermonuclear explosions in white dwarfs, type II supernovae result from the collapse of a massive star. When the outside of a SN II is ejected, it is still mostly hydrogen. The properties of the expanding, cooling atmosphere can be computed in detail and this was done by Ron Eastman, a postgraduate student in Kirshner's group (Eastman & Kirshner 1989). By repeated measurements of the temperature, speed, and brightness of the

supernova atmosphere it is possible to figure out how large the atmosphere is and compute the distance to the explosion. Schmidt teamed up with Eastman who was "writing a very fancy computer code" which modelled what was happening in the supernova from a physical basis. "I worked with Ron Eastman and Bob very carefully to model these supernovae and that told us how many watts they put out so that we could therefore know how bright they appeared on Earth, compare that to how many watts intrinsically they were, and using the inverse square law, the fact that light gets fainter by distance squared, measure the distance directly to objects outside of the local universe". Using the expanding photosphere method he measured fourteen supernovae for his PhD thesis. This enabled him, "to measure a value of the Hubble constant which was independent of any other means and could be compared directly with cepheids and it turns out the value I got, 73 plus or minus eight kilometres per second per megaparsec" was very close to the now accepted value of about 72 km/s/Mpc (Schmidt B et al. (1994)). It is interesting to note that some of the galaxies with SN II data and expanding photosphere distances were also galaxies in Wendy Freedman's Key Project sample. The results agreed very well.

At the time he was doing his work on supernovae II there were two other groups who were also measuring the Hubble constant (H_0). There was controversy and acrimonious debate as to what was the real value. In the 1970s Gerard de Vaucouleurs then at the University of Texas and a past member of the academic staff of Mount Stromlo Observatory favoured a high value for H_0, of around 80 or 90 while Alan Sandage and Gustav Tammann strongly maintained that 50 was the correct answer. Sandage, a protégé of Hubble (Overbye (1991)) believed that he owned H_0 and anyone who did not accept this value was an idiot or a country bumpkin. The debate dragged on into the 1990s. According to Schmidt, "there was the Sandage, et al. group who were convinced it was 50. There was the Mould, et al group who thought it was 80 something but were not quite sure". Schmidt started out with a value of 60 but "then we re-did the models and made some improvements and it drifted to 73. So at 60 I was very popular with Alan Sandage. At 73 he called me a traitor. I think he has forgiven me".

Schmidt's PhD thesis was significant and it provided confirmation of the Key Project team's measurements of the Hubble constant with the Hubble Space Telescope of 72 kilometres per second per megaparsec. The key project work was mostly carried out by Jeremy Mould and Brad Gibson at Mount Stromlo Observatory. Other key players were Wendy Freedman at Carnegie and Rob Kennicutt at the University of Arizona (Freedman et al. (2001)). According to Schmidt the work he did on the Hubble constant "was a good grounding in what came later, the accelerating universe".

It was unusual to be given an internal job straight after a PhD at Harvard but that was exactly what happened in the case of Schmidt when he finished his PhD in 1993. According to Kirshner, "Although we usually liked to push the fledglings out of the nest, Brian was so extraordinary he won one of the competitive postdoc jobs at the Centre for Astrophysics. This gave him the chance to step out as an independent worker" (Kirshner 2002).

To Australia and the accelerating universe

On a visit to Harvard, Mario Hamuy from Chile not only showed Schmidt and his colleagues new supernova data but also showed them "very clearly you could use Type Ia supernovae to measure accurate distances". According to Schmidt, "In 1991, there was the idea that Type Ia supernovae were perfect standard candles. I

was very sceptical about using Type Ia supernova for cosmology because we didn't know very much about them". In 1991 two unusual supernovae, SN 1991T and SN 1991bg were discovered. They strengthened the case that there were real differences among SN Ia and their discovery cast doubt as to whether SN Ia could be used as standard candles (Leibundgut et al. (1993)). Supernova 1991bg was intrinsically faint and appeared to be ten times fainter than an earlier SN Ia in the same galaxy. It rose and fell much more quickly. On the other hand SN 1991T was exactly the opposite, it was much brighter and it rose and fell more slowly. This intrigued Mark Phillips and by plotting the luminosity of several supernovae he found that the rate supernovae rise and fall is a very good indicator of how bright they are intrinsically (Phillips (1993)). According to Schmidt, "that was the relationship with a new, independent dataset that was shown to me in 1994. They found that Phillips' relationship made the supernova behave very nicely, you can measure distances to about eight per cent in accuracy which may not sound brilliant on Earth, but in astronomical terms when we are used to everything being about thirty per cent, that was good. Eight per cent was outstanding". Mario Hamuy had taken Phillips idea and turned it into a solution to the puzzling luminosity differences in the supernovae in a paper of which he was the first author (Hamuy et al. (1996)). In fact, he showed that Phillips was correct. The slow declining supernovae are the bright ones and the fast decliners are the faint ones. By measuring how fast a Type Ia supernova fades after it reaches maximum brightness, you were not likely to make any mistakes in assigning it the wrong distance. The scene was set for using Type Ia supernovae as distance indicators.

In the same month Schmidt had found out that Saul Perlmutter and his group at the University of California, Berkley had found seven distant objects to enable them to trace back the expansion history of the universe. They had begun a serious study of supernovae in the late 1980s with a combination of Rich Muller from the Physics Department and the Lawrence Berkeley Laboratory, including Carl Pennypacker (Filippenko et al. (2001)). Alex Filippenko from the Astronomy Department joined them sometime in 1994. Perlmutter, with a forceful personality joined them later and became the leader of the group although he was quite a junior academic. Schmidt's view was that "if those guys at Berkley can find supernovae, we sure as hell can. We had all the supernovae expertise, let's get out and do that". That was the genesis of the High-Z Supernova Team. It was formed at about the time Schmidt arrived in Australia at the Mount Stromlo Observatory. He was twenty-seven years old. It is rather remarkable that he was going to lead an international team to explore the past history and the future of the universe at that young age. He said, "I knew I wanted to go back and measure the past history of the universe, but this was going to require telescope time which I did not have access to in Australia". He worked out a strategy to unveil the secrets of the universe. "We needed the world's largest telescope, the Keck telescopes, we needed access to the Hubble Space Telescope. We needed a big whack of time on the wide field imager on the Cerro Tololo four metre. And so I went through and I took the people I knew in supernovae which was the Chileans, who helped determine the relationship that allows us to use them. Alex Filippenko from Perlmutter's group at Berkeley joined us in 1995 when the power of the Keck telescope became apparent. Filippenko had access to Keck. Chris Stubbs, who worked on the MACHO experiments here and was someone who was interested in large data sets was invited. Bob Kirshner, my supervisor for his general expertise and Bruno Leibundgut who had access to European

facilities". They started with about fourteen people which eventually became twenty.

In 1995 they found their first supernova – called Supernova 1995 K which turned out to be an extremely interesting supernova. The supernova was 40% fainter than he had expected it. "This single object seemed to show that the universe is speeding up", he said. But to provide concrete evidence they needed more objects.

1998 was Schmidt's year. It began with publishing a number of papers which tackled the problem of the state of the universe, experimental techniques to study the universe and the equation of state of the universe (Garnavich et al. (1998a), Garnavich et al. (1998b), Riess (1998), Schmidt et al. (1998)). "At the end of 1997, Peter Garnavich had put together four new objects (five in total) now, and these showed that the universe was not slowing down quickly. It was a month later when Adam Riess (along with Schmidt and Garnavich – who were the three postdocs in the group) assembled fourteen objects that we saw the signal of acceleration", Schmidt informed me. So in 1998 they showed that the universe wasn't slowing down at all. Indeed, it seemed to be speeding up. According to Schmidt, "It was a big thing because here we have observations that the universe is speeding up. What does it mean? It means that the universe has to be full of an energy which pushes on the universe rather then pulling it. We were telling the world that seventy per cent of the universe is made up of a material that you did not know existed. That is, there is something out there ripping the universe apart which is the most fundamental thing in the universe and we never knew it existed. And we did this with the Perlmutter group who turned out had independently made the discovery. Our papers came out ahead of theirs. They hit the press release before we did. Anyway, the important thing is that the two groups were independent".

It was a remarkable discovery. It was all the more remarkable because although there was not much love lost between the two groups when they first began on this quest they ended up by agreeing that the universe is accelerating. The discovery was Science Magazine's discovery of the year for 1998. Einstein's blunder was not a blunder after all. One recalls that earlier in the 20th century Einstein had added a cosmological constant to his general theory of relativity to balance the motion of the universe so that it would be stationary. So, I asked Schmidt whether his accelerating universe confirms Einstein's theory? According to Schmidt, "In some sense it does. I'm not sure whether it confirms it but it certainly is pointing towards the cosmological constant. But it is hard to understand why the cosmological constant is so small and not zero".

Supernovae provide the only evidence for acceleration but when combined with the microwave background an interesting picture of the universe emerges. The measurements allowed the astronomers to pin down how much dark energy (Ω_λ) and how much dark matter (Ω_m) the universe contains. The supernova data gave a value of $\Omega_m - \Omega_\lambda$ and the cosmic microwave background (CMB) measurements gave a value of $\Omega_m + \Omega_\lambda$. So in their paper on the constraints in cosmological models the High-Z Supernova team crossed the data from supernova with that of the CMB (Garnavich et al. (1998b), Tonry et al. (2003)) and to their amazement found $\Omega_m = 0.3$ and $\Omega_\lambda = 0.7$. In effect, the results were telling the astronomers that in the early universe the density of matter in the universe was greater than now and at some point in time dark energy took over to give us an accelerating universe in which we live today. But the astronomers don't

have a clue what the dark energy is that is accelerating the universe.

Has the problem of the cosmological parameters been completely solved or were there some other problems which needed to be resolved, I asked Schmidt. According to him, "I'm fairly heretical on this. And I believe we've done most of it. The theorists are aching to show that it isn't the cosmological constant. My view is we've shown that it's close to the cosmological constant. And I think we can probably improve things by a factor of three with $1 billion. That's where we are at. A billion dollars gives you a factor of three improvement in our measurement. And if the billion dollars do not show anything, that's a very expensive billion dollars for not a lot of gain. So that is where we are heading, measuring the equation of state. But it's not something that interests me. I'm doing it as a sideline, but I'm trying to shift my focus to other things because I think we have done most of what we can do and it's time to move on to other problems which are more interesting".

Skymapper

He is the team leader of the SkyMapper project (http://www.mso.anu.edu.au/skymapper) which will be constructing a comprehensive digital map of the southern sky. He said, "It will produce a petabyte of data. It will be used to find very rare objects and help us answer a whole range of different science issues". So what were the issues he was trying to solve. According to him, "There are a few intrinsically bright, but not too bright quasars that were formed at the dawn of the first stars. And there are three known right now from the northern hemisphere search which did not go as far as the SkyMapper will go and has not done as much sky area. And so, we should be able to take those three objects and make twelve or fifteen. And those objects will allow us to probe the universe and see how the universe turned on, and what age it did and the process behind it". The objects could also be used as places to undertake radio observations with the Murchison Widefield Array to look at the hydrogen before it was ionised – a project being worked on by a range of astronomers across Australia, and the US at MIT and Harvard. He hopes to feed objects for them to look at.

Another interesting thing he said, "we can do is to look at the first stars in our galaxy. We can actually pinpoint the stars that have almost nothing other than hydrogen and helium in them by their colours. And right now this university (i.e., the Australian National University) is leading this area of research".

The Oort Cloud which was first postulated by the Dutch astronomer Oort will also come under his scrutiny. It is the home of comets. "Paul Francis will be using the SkyMapper to find out what's going on in the Oort Cloud by seeing what is going on in the outer solar system with these comets as they come into our neighbourhood". He sees the SkyMapper as a great resource "not just for me, but for the entire astronomical community". As we roamed over a number of astronomical topics and drank several cups of coffee, I finally asked Schmidt what he considered was the major achievement in his life to date? "Certainly the accelerating universe is a level above everything else I have done and probably will ever do. It is my hope that SkyMapper will come close to the accelerating universe. It will not reach the novelty of the accelerating universe but my hope is it will be a major iconic piece of work at that level. The work we have done in gamma ray bursts has been good. The work on supernova physics and the Hubble constant was actually quite an influential piece of work". Perhaps, we will hear of more major discoveries with the SkyMapper in future years.

Conclusion

This paper has shown some aspects of the life and scientific achievements of one of Australia's foremost astronomers. It has revealed the steps that led to the discovery that the universe is accelerating and the amount of dark matter and dark energy the universe contains.

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Effects of coconut water on callus initiation and plant regeneration potentials of sweetpotato

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Abstract

Embryogenic callus initiation and plant regeneration in sweetpotato *in vitro* have been accomplished through various amendments with supplements. Such amendments include use of appropriate growth regulator combinations or inclusion of other supplements that have the potentials to enhance callus initiation and shoot proliferation. Coconut water has been reported to enhance callus induction, shoot development and multiplication in tissue culture of plants but has never been tried in sweetpotato, which is still recalcitrant to most *in vitro* treatments reported. The objective of this study was to evaluate callus initiation; shoot proliferation and plant regeneration potentials of four different quantities of coconut water levels ($0mlL^{-1}$, $25mlL^{-1}$, $50mlL^{-1}$, $75mlL^{-1}$ and $100mlL^{-1}$) on three sweetpotato cultivars of Papua New Guinea *in vitro*, on a modified Murashidge and Skoog (MS) medium. The modified medium was supplemented with $3mgL^{-1}$ 2, 4-dichlorophenoxyacetic acid and $0.5mgL^{-1}$ 6-benzyl amino purine. The control medium was set without any of the coconut water levels. At coconut water levels lower than $75mlL^{-}$, callus initiation and plant regeneration potentials of all the sweetpotato cultivars were relatively low. At coconut water levels of $75mlL^{-1}$or higher, more than 85% of SK010, 75% of WHCH005 and 50% of PRAP496 initiated callus that were capable of proliferating into shoots. Shoot proliferation was also poor at lower coconut water levels. Shoot isolates that proliferated from calli at higher coconut water levels were able to grow to maturity.

Keywords: Coconut water, callus initiation, plant regeneration, sweetpotato

Introduction

Sweetpotato (*Ipomoea batatas L.*) genetic resources are an important component of the biological diversity in Papua New Guinea (PNG) where cultural and environmental diversity exist. PNG has a rich array of cultivars, semi cultivars or landraces of more than 1500 sweetpotato (SP) that are adapted to different environmental conditions. The richness in diversity and the existence in the light of growing shift from mixed cultivation to monoculture in the farmers' fields, continuous degradation of soil fertility, rapid population increases, lack of proper farm management practices, introduction of pests and diseases and unpredictable weather patterns coupled with natural disasters have indicated growing need for SP genetic diversity conservation, use and improvement. As a result of these factors, there is an irreplaceable erosion of SP genetic resources once found and face the serious risks of losses if no proper efforts towards sustainable utilization and management of the richness in diversity are addressed (Michael, 2004).

Traditionally, SP is conserved by subsistence farmers because of the mixed cropping systems practiced, and it is not surprising to find thirty to fifty different cultivars in the farmers' fields. The presence of the diversity shows how

important this crop is and the wide spread acceptance of the crop by the people, especially in the highlands where the population density is often high and SP plays an important role in the lives of the people socio-economically (Michael, 2004). Not only that, it is also reported to be an important food security crop in many other developing countries (Burden, 2005), especially in the tropical, subtropical and warm temperate regions of the world (Sihachakr et al., 1997).

Despite the importance of SP, the crop is often subjected to disease causing pathogens, prone to pest and disease infestations (Aritua et al., 1998) and there is a need to improve the crop genetically. The genetic improvement of the SP however, is limited due to male sterility (Sihachakr et al., 1997; Otani and Shimada, 2002; Song et al., 2004), incompatibility and the hexaploid nature of the SP genome (Dhir et al., 1998; Michael, 2005; 2009). These limitations have prompted SP researchers to use alternative techniques such as genetic manipulation (transformation) and several plant tissue culture techniques (Michael, 2005; 2009; 2010). Plant tissue culture underpins many of the *in vitro* techniques in genetic manipulation and plays an important role in the manipulation of plants for micopropagation of planting materials, elimination of tissue borne disease causing pathogens such as virus, isolation and development of genetic variants and conservation of plant genetic resources *in vitro* (Michael, 2005; 2007).

There are several reports of embryogenesis and organogenesis in SP tissue culture and plants have been reported to be regenerated through somatic embryogenesis through roots (Jarret et al., 1984) and root disc (Carswell and Locy, 1984). Despite the advances made in SP tissue culture, the crop is still recalcitrant to different *in vitro* treatments in terms of plant regeneration from callus (Michael 2005; 2009) and many amendments have to be made to the mineral composition or the growth regulator combinations used. Such amendments include the use of correct combination of growth hormones and inclusion of other *in vitro* callus induction and proliferation factors, such as coconut (*Cocos nucifera L.*) extracts (Michael, 2007).

The report of Agampodi and Jayawardena (2009) shows that coconut contains plant growth hormones that are normally used in tissue culture. Similarly, other research reports show that supplementation of coconut water in tissue culture media has enhanced callus initiation (Namdeo et al., 2006), shoot development (Tefera and Wannakrairoj, 2004) and multiplication in combination with synthetic auxins (Loc et al., 2005) in plants. Despite these works, the applications have been limited due to low reproducibility (Saranga and Cameron, 2007; Agampodi and Jayawardena, 2009) and the uses of coconut water in SP tissue culture have never been reported. This study was conducted to test the effects of five different coconut water levels (CWL) on callus initiation, shoot proliferation and plantlet regeneration potentials of three sweetpotato cultivars *in vitro.*

Materials and methods

Field practices and sources of plant materials

The cuttings of three SP cultivars used in the present study were supplied by PNG National Agriculture Research Institute (NARI). The cultivars were high yielding, drought tolerant and widely cultivated SP cultivars (SK010, WHCH005 and PRAP496) in the PNG highlands. The respective cuttings of the cultivars were potted out in a compost mixture of farm yard manure and sand in the proportion 3:1 and grown to maturity under glasshouse conditions at the Department of Agriculture, PNG University of Technology, as sources of explants. The plants were watered daily and a slow release, granular fertilizer (NPK, 15-15-15) was applied to support normal plant growth. Cuttings from these plants were used as source of explants throughout the study.

Surface sterilization and explant preparation

For laboratory use, the top shoot tips on the youngest nodes containing 2-3 leaf primodia of 2 months old plants were sampled, placed in several vials containing 20ml of reverse osmosis water to prevent explants dehydration and taken to the lab for immediate use. For culture initiation, the nodes between the first and the second most youngest leaves of the shoot tips of all cultivars were cut into required sizes (~3mm) and surface sterilized by placing them in pre-labeled 100ml beakers containing 20% sodium hypochlorite (NaOCl) for 5 minutes followed by rinsing them in sterile reverse osmosis water under a sterile cabinet for 3 minutes. The sterile stocks were further excised (~2mm in length), cut transversely into sections and again in half along the axis and used as explants.

Coconut water and medium preparation

The CWL were prepared using young nuts (~9 months old), collected from the Agriculture Department Farm, PNG University of Technology. The nuts were cracked opened and the water was sieved through a double-folded muslin cloth, 2-3 times into several 100ml plastic vials with screw caps and kept frozen in a freezer at -4°C prior to use.

The modified MS-based medium consisted 3mgL^{-1} 2, 4-dichlorophenoxyacetic acid (2, 4-D), 0.5gL^{-1} polyvinylpyrrolidone (PVP) as an antioxidant, 0.5mlL^{-1} 6-benzylaminopurine (BAP) and 30gL^{-1} sucrose as energy source. Agar at 8gL^{-1} was used as the gelling agent (MS0.8 medium). The auxin-cytokinin combinations used was based on previous studies on sugarcane tissue culture research (Michael, 2007) in our lab at the University of Technology Biotechnology Centre (UBC). To identify the optimum CWL, a range of CWL (0ml, 25ml, 50ml, 75ml and 100ml) were supplemented in a litre of MS0.8-based medium. A litre each of CWL was prepared (a total of 8L (4L for callus initiation and 4L for direct plant regeneration respectively)). The control medium contained all the supplements except the CWL (MSCo.8 medium). Two litres of MSCo.8 medium was prepared.

The callus initiation medium contained all the supplements together with the different CWL (MSCi.8 medium) and the medium for plant regeneration contained the same supplements and CWL except 2, 4-D (MSCr.8 medium). The pH of the media was adjusted to 5.6 with 1N sodium hydroxide (NaOH) and heated on a hotplate with continuous stirring until all the supplements have dissolved. A 25ml of the media were dispensed using a manual dispenser into 25ml plastic vials, followed by sterilizing in an autoclave at 15psi (121°C) for 15-21 minutes. A total of 40 vials containing 25ml of the medium per litre each of the CWL and control were prepared. This procedure was followed subsequently to prepare all the media required throughout the study. A total of 28L of both the control and treatment media were prepared.

Culture initiation and plant regeneration

All the explants were handled aseptically. The meristematic tips for callus initiation were further excised into segments (0.5-1.0mm), wounded throughout and cultured on MSCi.8 medium. Five explants were cultured in a vial of each CWL and replicated 5 times. A total of 20 vials each were allocated to each SP cultivar (5 vials per CWL), and cultured with 100 explants. There were 60 vials cultured with a total of 300 explants of all the cultivars; and set up using a complete randomized design. The cultures were incubated inside dark cupboards and routinely sub-cultured at 3 weeks intervals for further callus initiation, proliferation and multiplication until adequate amounts of calli were obtained (Table 1).

For plantlet regeneration, 28 day old embryogenic calli (EC) were transferred onto fresh MSCr.8 medium and incubated directly

under a 16 hour photoperiod of 30μmol $m^{-2} s^{-2}$ photosynthetic photon flux using cool white fluorescent tubes in an incubation room as per Michael (2007) at a room temperature of 24±2°C. The miniature shoots of about 3-5cm long with small roots obtained from callus were singled out and transferred onto fresh MSCr.8 medium for rooting. Plantlets were further rooted on an MSCr.8-based medium supplemented with 0.5mgL^{-1} cytokinin (BAP), prepared separately for this purpose and grown to maturity. These cultures were kept under reduced *in vitro* conditions at half the original strength of MSCr.8 medium and conserved. The conserved materials were routinely sub-cultured every 6 months and maintained throughout. This procedure developed was adapted and is routinely used in our laboratory at University of Technology Biotechnology Center (UBC).

Data collection and statistical analysis

Callus growth was assessed by taking the differences between the final and initial calli weights. The initial calli weights were obtained by weighing all the calli during the first subculture and the final weights by weighing the same cultures during the second subculture respectively; within 28 days at an interval of two weeks, until transferred to the MSCr.8 medium for further calli proliferation, shoot initiation and plant regeneration. The data collected were entered on Microsoft Excel 2007 and stored prior to analysis. The callus growth data collected were analyzed using Statistix 9.1 (Statistical Software). One-way ANOVA was also done to test the significant differences between different treatments (CWL) at $p<0.05$. The analyzed data presented in Table 2.

Results

Callus initiation potential

The callus initiation potentials of the explants (meristem tips) cultured on the modified MS-based media containing the different CWL gave different results, showing strong cultivar responses to the *in vitro* treatments provided. Compared to MSCr.8 medium, the explants and callus cultured on MSCo.8 medium were comparatively low in terms of callus and shoot initiation, proliferation, and development. The callus initiation potentials of the cultivars in the order of responsiveness were SK010, WHCH005 and PRAP496 (Table 1).

Cultivar	Coconut water levels (mlL^{-1})				
	0	25	50	75	100
SK010	10	13	20	56	86
WHCH005	6	8	15	43	77
PRAP496	3	4	11	23	63
The percentages were calculated based on the total number of explants that induced callus raised over the total number of explants (125) cultured per CWL on MSCi.8 medium. The data under zero (0) CWL are the performances of explants cultured on the control medium (MSCo.8).					

Table 1. Callus initiation potentials as percentage (5) of meristem tips of the three sweetpotato cultivars.

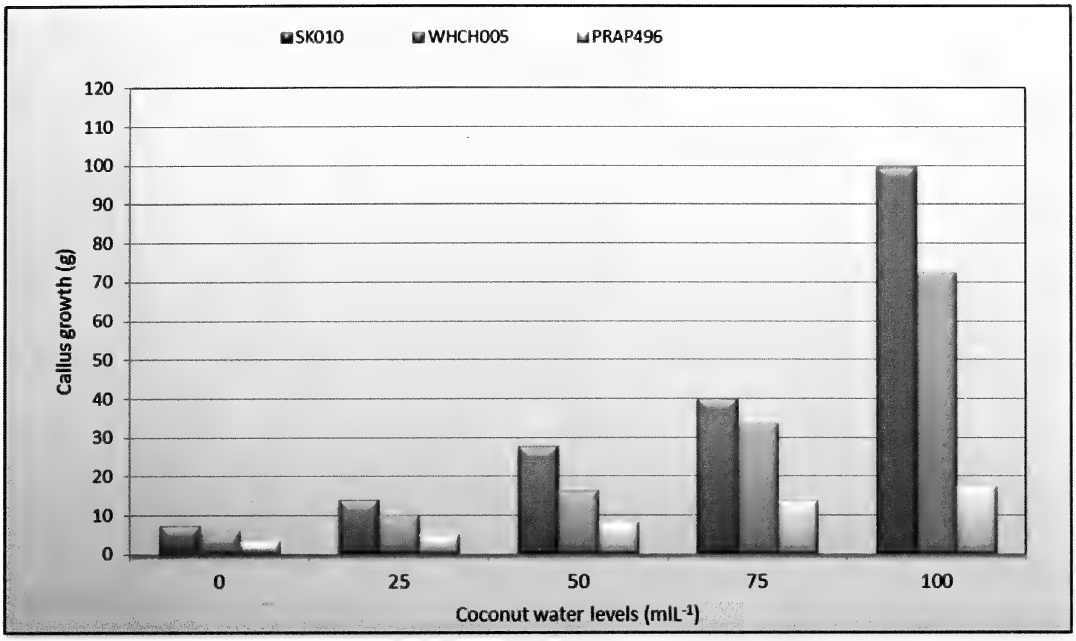

Figure 1. Callus proliferation of the three sweetpotato cultivars on CWL. The data used (mean weights) are the differences between the callus weights obtained during the first subculture and at the second subculture respectively.

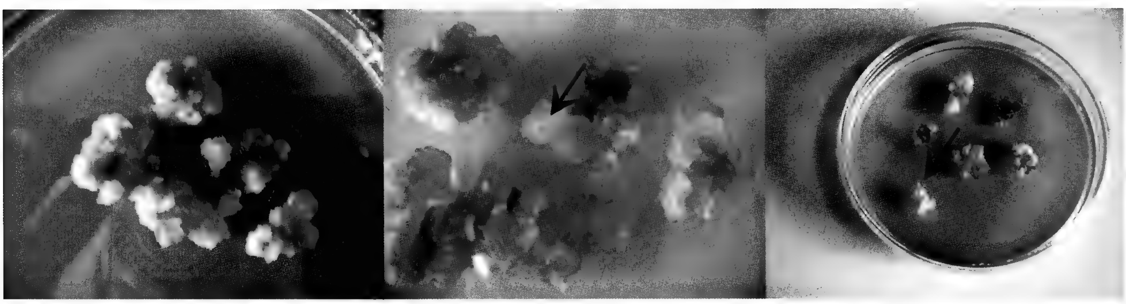

Figure 2A *Figure 2B* *Figure 2C*

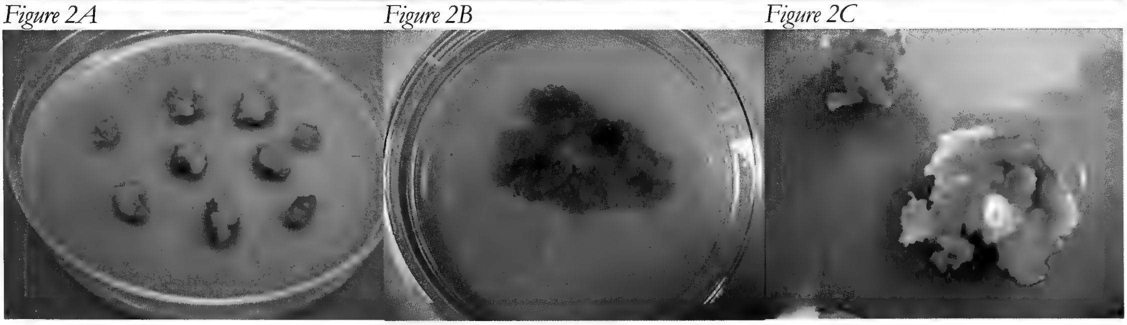

Figure 2D *Figure 2E* *Figure 2F*

Figure 2. Callus initiation on MSCi.8 medium. Callus developing on SK010 (A), WHCH005 (B) and PRAP496 (C) at 100mlL-1, and PRAP496 (D), SK010 (E) and WHCH005 (F) on 75mlL-1 21 days after culture respectively. The arrowheads show white and friable embryogenic (embryo-like) calli.

Embryogenic callus initiation and proliferation

There was a huge difference in terms of callus proliferation (growth) of the entire test SP cultivars used. In terms of callus initiation, all the cultivars performed poorly at lower CWL (25-50mlL^{-1}) on MSCi.8 medium. At CWL of 75mlL^{-1} or higher, most of the explants responded well and varying amounts of calli were obtained (Fig. 1).

Most of the calli produced at lower CWL were however, hard, friable and non-embryogenic in nature (Fig. 2D (full data not shown)). At 75mlL^{-1}, all the cultivars were able to induce and produce calli that were somewhat EC in nature but slightly at lower rates. Interestingly, at CWL of 100mlL^{-1}, all the explants of all the SP cultivars responded well and huge amount of calli were induced (Fig. 2). These calli were embryogenic in nature and had high regenerative potentials (Fig. 3). When the SP cultivars were compared in terms of callus initiation at 100mlL^{-1}, more than 85% (106/125) of cultivar SK010 (Fig. 2A), 75% (94/125) of WHCH005 (Fig. 2B) and 50% (63/125) of PRAP496 (Fig.2C) meristem tips induced callus on MSCi.8 medium (Table 1). One-way analysis of variance showed that all the higher CWL used for inducing callus were significantly different with p-values of the CWL 75mlL^{-1} [0.00 (WHCH005), 0.03 (PRAP496), 0.25 (SK010)] and 100mlL^{-1} [0.01 (WHCH005), 0.05 (PRAP496), 0.24 (SK010)) respectively.

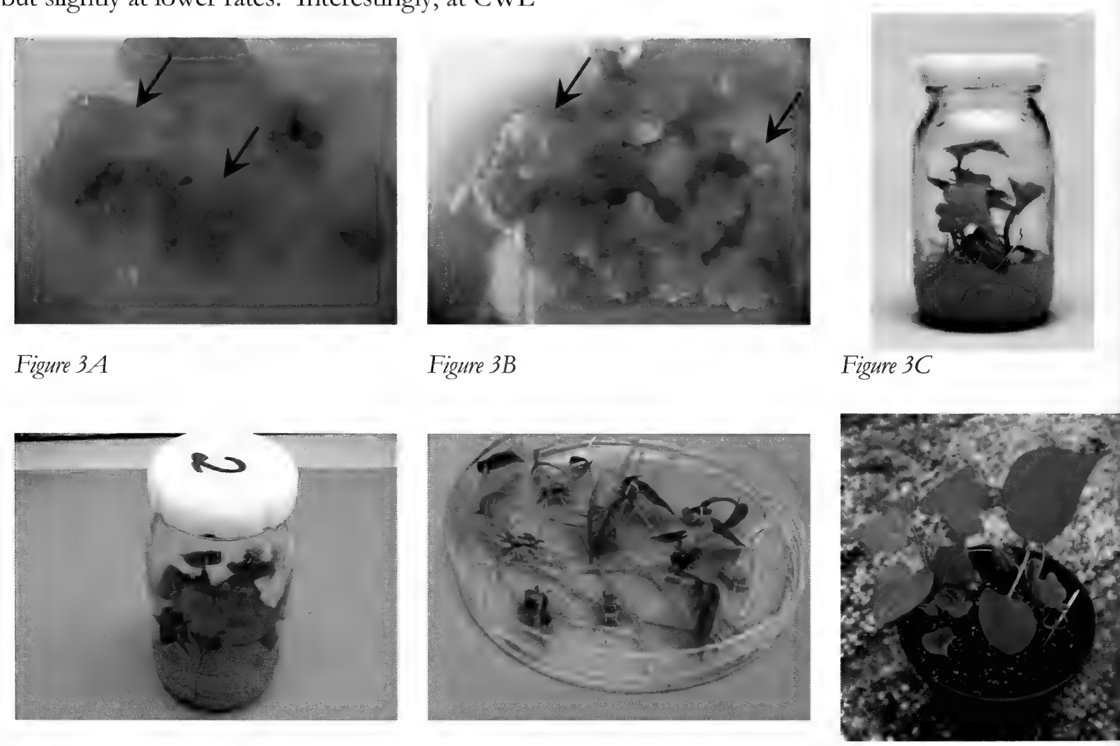

Figure 3A *Figure 3B* *Figure 3C*

Figure 3D *Figure 3E* *Figure 3F*

Figure 3. Plantlet regeneration on MSCr.8 medium. Proliferating EC of SK010 (A), WHCH005 (B), miniature shoot isolates from calli rooting (C), a single plant isolate grown to maturity (D), meristem tips generating shoots (E), and a shoot isolate grown to maturity (F). The arrowheads show calli proliferation (greenish) into miniature shoots.

Plantlet regeneration.

When selected EC were isolated and transferred onto MSCr.8 medium (Fig. 2), more than 90 percent proliferated into miniature shoots within 28 days after transfer (data not shown). Callus proliferation was high on CWL higher than $75mlL^{-1}$. The cultivar SK010 had a higher regeneration potential (Fig. 3A) followed by WHCH005 (Fig. 3B).

The cultivar PRAP496 was recalcitrant to any of the *in vitro* treatments used in this study in terms of plant regeneration. Comparatively, calli proliferation and shoot initiation of PRAP496 was also low, when transferred onto MSCi.8 medium (Table 1).

Coconut water levels	Sweetpotato cultivars		
(CWL)	SK010	WHCH005	PRAP496
$0mlL^{-1}$			
Mean	7.20	5.80	3.20
Standard deviation	2.17	0.84	0.84
Variance	4.70	0.70	0.70
Standard error means	0.97	0.37	0.37
Coefficient of variation	30.11	14.43	26.15
$25mlL^{-1}$			
Mean	13.80	9.80	5.20
Standard deviation	1.48	2.86	0.84
Variance	2.2	8.20	0.70
Standard error means	0.66	1.28	0.37
Coefficient of variation	10.75	29.22	16.09
$50mlL^{-1}$			
Mean	27.60	16.20	8.20
Standard deviation	7.83	3.11	0.84
Variance	61.3	9.70	0.70
Standard error means	3.50	1.39	0.37
Coefficient of variation	28.37	19.23	10.20
$75mlL^{-1}$			
Mean	27.60	33.60	13.60
Standard deviation	7.83	9.48	3.05
Variance	61.30	89.80	9.30
Standard error means	3.50	4.24	1.36
Coefficient of variation	28.37	28.20	22.42
$100mlL^{-1}$			
Mean	99.60	72.20	17.20
Standard deviation	21.10	11.19	4.44
Variance	445.30	125.20	19.70
Standard error means	9.44	5.00	1.98
Coefficient of variation	21.19	15.50	25.81

The mean weights (g) were calculated by dividing the total callus weights of each CWL by the total number of culture vials. Standard deviation, coefficient of variation and standard error means of each CWL are also shown.

Table 2. Assessment of callus proliferation (growth) by coconut water levels.

Root initiation in all the plantlets began immediately after the first pair of leaves have emerged and got fully established during the 2nd pair of leaf development (Fig. 3C). When the meristem tips of such plants were isolated, excised into single nodal segments and transferred to MSCr.8 medium (Fig. 3E) for shoot multiplication, the mini explants responded to the medium well at CWL higher than $50mlL^{-1}$ and somewhat got hardened, followed by mini root development.

When the roots were fully established in the medium, small shoots started protruding from the dormant buds on the nodes (Fig. 3E). Most of the plants derived from both callus and nodal segments rooted well and such plants were successfully isolated and grown to maturity under glasshouse conditions (Fig. 3F). Comparatively, callus initiation, proliferation and regeneration of plants on the MSCo.8 medium were poor. Callus initiation rate was slow and explants got dehydrated and wilted within 4 weeks of culture with little or no response, which were later discarded.

Discussion

The report of Mamaril et al. (1986) shows that growth factors have been successfully isolated from coconut water, however; their (growth factors) uses in SP tissue culture have not been tested. The observations made in this study showed that more than 50 percent of the explants cultured on the different CWL were potentially capable of inducing callus with strong cultivar differences at higher CWL (Table 1). Comparatively, more callus was produced by SK010 than WHCH005 and least by PRAP496. When performances of callus were compared among the different CWL, callus initiation and proliferation rates were concentration dependent. At lower CWL, callus proliferation was low whereas it was high at higher CWL (Table 1). Similarly, plant regeneration was low comparatively although the cultivars SK010 and WHCH005 showed some favorable responses. The latter two varieties also produced huge amount of calli at higher CWL ($100mlL^{-1}$).

When selected EC was transferred onto the MSCr.8 medium containing higher CWL ($100mlL^{-1}$), more than 80 percent of the calli produced miniature shoots (Fig. 3C) within 28 days, which later developed into whole plants (Fig. 3D). It was seen that the surface of the white EC, such as those shown in Figure 2A, B, C, turned slightly brown within 14 days after transfer (Fig. 3A, B), followed by greenish appearances on proliferating calli surfaces (Fig. 3A, B). Such surfaces, produced multiples of shoots which were later isolated and transferred onto fresh MSCr.8 medium for further growth and development (Fig. 3D). As shown in Figure 2, the calli induced on cultivars SK010 and WHCH005 were white in nature whereas Triqui et al. (2008) however, reported producing reddish calli which underwent various stages of callus growth. These workers observed that the calli were milky and mucilaginous. Likewise, the calli induced in this study were also milky and mucilaginous in appearance with high regenerative potentials (Fig. 2A, B).

Sihachakr et al. (1997) have shown that somatic embryos at cotyledonous stage turned green and gave rise to 3-5 plantlets per cluster of embryos cultured. In this study, embryo-like clusters of a small amount of greenish callus isolated and transferred onto fresh MSCr.8 medium also produced similar number of plantlets (Fig. 3C). It was also seen that plantlets rooted well when transferred onto the MSCr.8 medium containing cytokinin (BAP) at $0.5mgL^{-1}$ alone, whereas results of similar experiments elsewhere needed an auxin-cytokinin combinations at lower concentrations (Triqui et al., 2008; Sihachakr et al., 1997. In earlier researches in sugarcane tissue culture in our lab at UBC, it was observed that $2mgL^{-1}$ of BAP together with $100mlL^{-1}$ of coconut water without an auxin source resulted

in well rooted sugarcane plantlets (Michael, 2007).

The differences in cultivar performances observed in this study are consistent with the results of other workers in SP tissue culture (Sihachakr et al., 1997; Otani et al., 1998; Song et al., 2004; Michael, 2005; Oggema et al., 2007; Triqui et al., 2008; Michael, 2009; 2010). The latter studies conclude that SP is still recalcitrant to *in vitro* treatments and every genotype needs specific amendments for successful plant regeneration. The observations made, to a large extent show that inclusion of CWL in the culture medium can be useful in SP tissue culture research although the role performed by the unknown constituents of the extracts at this stage is not yet clear and warrants further research.

Studies using coconut water elsewhere show that coconut water is rich in lysine, cystine, histidine, methionine and other essential amino acids (Thio, 1982), has a high concentration of vitamins and minerals together with potassium, calcium and magnesium (Gopikrishna et al., 2008) and contains a lot of sugars (Jackson et al., 2004). Because the performances of explants or the callus cultured on MSCo.8 medium or at lower CWL were poor in terms of callus initiation, proliferation and plantlet regeneration, it is safe for this study to conclude that the higher callus initiation and proliferation, including regeneration potentials observed at higher CWL may be due to presence of growth promoting factors in the higher CWL as reported by other researchers (Thio, 1982; Gopikrishna et al., 2008; Jackson et al., 2004). The findings reported here have been tested, applied and used in tissue culture researches within our lab using other plants such as taro (*Colocasia esculenta*), yam (*Discorea esculenta*), licorice (*Licorice* sp.), noni (*Morinda citrifolia*) and Irish potato (*Solanum tuberosum*) and worked quite well. The MS-based medium (MSCr.8) has been adapted in our lab for conservation of *in vitro* micropropagated crop plants at reduced strengths also.

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Thesis abstract

Polymer brush carbon nanotubes as nanofillers in macro and nano-size composites

Tony John Aitchison

Abstract of a thesis for a Doctorate of Philosophy submitted to Flinders University, South Australia

The work outlined in this thesis covers the many aspects of carbon nanotubes and polymers by combining the two into nanocomposite materials of macro and nano size. The issues of producing and combining the two are explored and results are provided.

There are four major aspects to this work;
1. *Polymer Brushed Carbon Nanotubes*: multi-walled carbon nanotubes (MWCNT) are surface functionalized with polymer brushes produced by activators regenerated by electron transfer (ARGET) atom transfer radical polymerization (ATRP). A "grafting from" approach was used as a higher grafting density would result and therefore it was necessary to functionalize the carbon nanotubes surface with hydroxyethyl-2-bromoisobutyrate (HEBI). This acted as the haloalkane (i.e., tertiary bromide) initiator sites in ARGET ATRP of styrene and methyl methacrylate. The successful growth of the polymer brushes were characterized for their chemical, kinetic and physical properties. In addition, polymer brushes of 2-hydroxyethyl methacrylate (HEMA) were grown by non-living means by attaching the HEMA monomer via the hydroxyl group to a carboxylic acid surface functionalized MWCNT and subsequently polymerized.

2. *Macro-sized Composites*: a composite of carbon nanotubes with homopolymers as the matrix, requires surface modification of the MWCNT to prevent nanotube aggregation. A homogeneous dispersion is necessary in order to produce improved properties for the composite. The 'macro' composite research involved the incorporation of polymer brush carbon nanotubes in concentrations of 0.1w/w% to 1w/w% (e.g. poly(methyl methacrylate) polymer brush carbon nanotubes in a poly(methyl methacrylate) matrix). The most improved composites obtained used polystyrene brushes in a polystyrene matrix, which was due to π-π stacking interactions. The composite material possessed improved mechanical strength, increased glass transition temperature and increased processability. Furthermore, the dispersion was maintained after processing with shear forces.

3. *Pyrene as a Model System*: 1-pyrenecarboxylic acid has a very similar architecture to MWCNT and for this reason was used to model the chemical synthesis of aspects '1' and '2' with polystyrene. The work showed similar enhancements in terms of mechanical strength, increased glass transition temperature and increased processability. Compared to polystyrene polymer brush carbon nanotubes the improvement was not as great, however the pyrene material did not exhibit limits of dispersion like the carbon nanotube filler.

4. *Nano-sized Composites*: This research utilized a hexagonal-packed cylindrical phase of a di-block copolymer melt, in an attempt to align the carbon nanotubes to the cylindrical phase. To

ensure their affinity for the cylinder phase, polymer brushes of polystyrene were used for a 30/70 poly(styrene-b-methyl methacrylate) melt. However, the nanotubes were found to disrupt the segregation process, and the phases did not form appropriately. This ultimately did not provide strong enough forces to align the carbon nanotubes, but indicates that because of their relative massive size, greater forces are required.

Future work has been recommended with alternative polymer brush carbon nanotubes as fillers and using electric fields, as they have shown to better orientate a hexagonal-packed cylindrical phase from a parallel orientation to a perpendicular orientation. This is a suggested technique that could help align the carbon nanotubes.

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Thesis abstract

Development of *in situ* cosmogenic ^{21}Ne exposure dating, and dating of Australian arid landforms by combined stable and radioactive *in situ* cosmogenic nuclides

Toshiyuki Fujioka

Abstract of a thesis for a Doctorate of Philosophy submitted to the Australian National University, Canberra, Australia

Australian arid landforms including stony deserts and dunefields were investigated regarding their chronologies and formation processes using *in situ* cosmogenic nuclides. *In situ* cosmogenic nuclides, produced at the Earth's surface by interaction of secondary cosmic-rays with mineral elements, offer the method to estimate surface exposure ages, erosion rates and burial ages.

Among cosmogenic nuclides, ^{21}Ne is stable, and thus has advantage on measuring long-exposure ages >4 Ma where radionuclides (e.g., ^{10}Be, ^{26}Al) cannot reach due to their decay. Major effort was devoted to develop a method for accurately determining *in situ* cosmogenic ^{21}Ne in quartz samples. In conclusion, evaluation of non-cosmogenic components, crustal ^{21}Ne using crushing analysis and *in situ* nucleogenic ^{21}Ne from U-Th analysis and rock ages, were regarded as to be the most reliable at this stage.

Cosmogenic ^{21}Ne and ^{10}Be in silcrete gibbers from central Australia were measured to evaluate the formation history of Australian stony deserts. Results show discordant exposure ages with excessive ^{21}Ne, implying pre-exposure at a shallow depth prior to exhumation of parent silcrete. A model correcting for pre-history nuclide accumulation suggests that the stony deserts formed as early as 4 Ma, dissection of silcrete-capped tableland occurred 2-3 Ma, and stripping of soils and silcrete exhumation occurred 1 Ma onward. This is the first to determine chronologies of stony desert formation in Australia.

With the aim of determining the initiation of dune-building in Australia, >60 dune samples were collected from nine drill-holes of five longitudinal dunes near Finke, west Simpson Desert, for cosmogenic-burial dating and OSL. The drill sampling identified palaeosol horizons, suggesting episodic nature of dune building at the sites. Cosmogenic ^{26}Al-^{10}Be burial ages indicate the basal dune ages of 1.2-1.3 Ma, significantly older than previously thought.

In summary, this PhD project demonstrates that: 1) evaluation of non-cosmogenic ^{21}Ne, such as crustal and *in situ* nucleogenic ^{21}Ne, is essential to determine low amounts of *in situ* cosmogenic ^{21}Ne, and both crushing and fusion gas-extraction experiments are the essential approach to achieve this; 2) combined ^{21}Ne and ^{10}Be measurements first reveals chronologies of Australian stony deserts, showing that the stony deserts developed during global cooling that initiated the Quaternary glacial cycles; and 3) Australian longitudinal dunes formed episodically, and the earliest episode can date back to 1.2-1.3 Ma, much older than previously

thought and similar to playa formation in central Australia.

Finally, this study showed usefulness of *in situ* cosmogenic nuclides, not only commonly-used radionuclides (e.g., ^{10}Be, ^{26}Al) but also stable nuclide (^{21}Ne), to investigate chronologies of arid landforms with the age over million years. Despite the relatively long exposure history, the measurement of *in situ* cosmogenic ^{21}Ne in central Australia remain difficult, due to its low production rate at mid latitude and low altitude, and also to old rock ages resulting high *in situ* nucleogenic ^{21}Ne. Nevertheless, usefulness of ^{21}Ne in desert landscape study is no doubt, and it will be valuable to apply ^{21}Ne to sites at higher latitude and altitude, where production rates are high, such as Gobi and Atacama Deserts.

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Thesis abstract

Exploring the missing links: a critical inquiry into the role of social capital in Australian regional development

Keri Chiveralls

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of South Australia, Adelaide, Australia

This thesis examines the role of social capital in Australian regional development. It does so though a case study of one of the most socio-economically disadvantaged regions in Australia, the City of Playford, (perhaps best known as the former City of Elizabeth and home of South Australian Manufacturing). The approach taken involves an examination of the historical roots, more recent academic and political debates, along with the structural political and economic conditions which have inspired the rise of social capital. This is accompanied by an exploration of the application and implications of the social capital approach to development in the City of Playford. Recent years have seen an explosion of interest in social capital theory. Of particular interest to policy makers has been the suggestion that there is a link between social capital and economic development. This argument has lent support to the idea that inequality in regional economic development can be tackled by building social capital in disadvantaged regions. In this thesis I take a critical approach to both the concept 'social capital' and the link between social capital and economic development.

I suggest that the popularity of social capital may be due more to the political and academic environment in which the concept was spawned, than its ability to address issues of inequality in regional development. The results of the case study in the City of Playford highlight the continuing importance of issues of class and structural inequality in Australian regional development. I argue that contemporary applications of social capital in regional development are not only unable to adequately address such issues, but may also be contributing to their exacerbation. Having drawn attention to the inherently problematic nature of the concept, I then discuss the implications of the research findings for the future of social capital in both policy and social theory.

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Thesis abstract

England elsewhere: Edward Gibbon Wakefield and an imperial Utopian dream

Michael Radzevicius

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Adelaide, Adelaide, Australia

British colonial reformer Edward Gibbon Wakefield (1796-1862) is most widely known in scholarly literature for the role that he played in the planning, promotion, and establishment of the British colonies of South Australia and New Zealand. Always a controversial historical figure, Wakefield's career as an advocate of British imperial expansion is a subject that continues to challenge modern scholars. Some view him as a contemptible, deluded capitalist visionary who had little practical impact upon the political landscape of his day. Others argue that his advocacy of a regulated, 'systematic' form of colonization provided the impetus for the rapid increase in British emigration to Australia and New Zealand in the 1830s and 1840s. What is common to almost all of the scholarship on Wakefield's life and works, however, is the view that his plans to colonize South Australia and New Zealand were attempts to create an ideal, utopian colonial society. The utopian qualities of Wakefield's works have been especially recognized in the historical literature of New Zealand.

In general, however, his works have been assessed in the context of colonial and imperial history, rather than as an important contribution to Western utopian literature. With its modern genesis in Thomas More's Utopia of 1516, the canon of Western utopian literature is large and has received extensive scholarly interest and investigation. Although utopian thinking is a multifarious literary and theoretical tradition open to diverse interpretations, there is nonetheless a readily identifiable canon of texts and authors that scholars have categorised as being 'utopian.' Wakefield's works are generally excluded from this canon and it is this gap in the intellectual history of the Western utopian tradition that this thesis addresses.

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Thesis abstract

Earth jurisprudence: private property and earth community

Peter Burdon

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Adelaide, Adelaide, Australia

The central argument of this thesis is that the institution of private property reflects an anthropocentric worldview and is contributing to the current environmental crisis. Drawing on the description of law as a mirror of society, it considers how our idea of law and the institution of private property can adapt to reflect the recent scientific description of human beings as interconnected and mutually dependant on nature. It advocates a paradigm shift in law from anthropocentrism to the concept of Earth community.

The thesis first provides an example laws anthropocentrism by exploring the legal-philosophical concept of private property. Private property is advanced over other legal concepts, because it plays a key role in governing human interactions with the environment and because it contains some of law's main messages about nature and our place within it. The thesis analyses three main influences on the development of private property from the humanism of antiquity, the scientific revolution and the influence of liberal political philosophy. It concludes that the dominant rights-based theory of private property is anthropocentric and facilitates environmental harm.

The second component of the thesis explores contemporary scientific evidence supporting the ecocentric concept of Earth community. This concept argues that human beings are deeply connected and dependent on nature. It also describes the Earth as a community of subjects and not a collection of objects. Assuming that the social sphere is an important source for law, this thesis considers how a paradigm shift from anthropocentrism to ecocentrism can influence the development of legal concepts. To catalyse this shift, it considers the 'new story' proposed by cultural historian and theologian Thomas Berry. This story describes contemporary scientific insights such as interconnectedness in a narrative form

Third, the thesis uses the alternative paradigm of Earth community to articulate an emerging legal philosophy called Earth Jurisprudence. It describes Earth Jurisprudence as a theory of natural law and advocates for the recognition of two kinds of law, organised in a hierarchical relationship. At the apex is the Great Law, which represents the principle of Earth community. Beneath the Great Law is Human Law, which represents rules articulated by human authorities, which are consistent with the Great Law and enacted for the common good of the comprehensive Earth Community. In regard to the interrelationship between these two legal categories, two points are crucial. Human Law derives its legal quality from the Great Law and any law in contravention of this standard is considered a corruption of law and not morally binding on a population.

Finally, the thesis constructs an alternative concept of private property based on the philosophy of Earth Jurisprudence. It describes private property as a relationship between members of the Earth community, through tangible or intangible items. To be consistent with the philosophy of Earth Jurisprudence, the concept of private property must recognise human social relationships, include nonreciprocal duties and obligations; and respond to the 'thing' which is the subject matter of a property relationship. A theory of private property that overlooks any of these considerations is defective and deserves to be labelled such.

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Thesis abstract

Diverging identities: a 'contextualised' exploration of the interplay of competing discourses in two Saudi university classrooms

Tariq Elyas

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Adelaide, Adelaide, Australia

There has been considerable debate in recent years and criticism levelled both from inside and outside sources at the English curriculum in Saudi Arabia. As the future English school teachers, Saudi University students studying English in Saudi higher institutions and the pedagogies employed by their lecturers are of particular interest in this regard. Some work has been done on Arabic students studying English in other Gulf countries on the social-cultural aspects of attitudes towards learning English as a language and the effect of English culture(s) on Saudi Arabian students and teachers. However, a detailed unpacking of the different cultural influences (both Islamic and Western), and how they are evidenced in policy documents, curriculum, textbooks and pedagogy, remains relatively unexplored. In addition, the effect of the various influences on the teachers' professional identities, and the students' learning identities has not been dealt with prior to this thesis.

The methodology for this thesis into the relationships between identity and Discourse drew from a number of intersecting theoretical perspectives, including Identity Theory, Narrative Theory, Motivation Theory and Critical Discourse Analysis.

The resulting case study described, analysed and interpreted the multi-layered complexities at play in the teaching and learning of English in two undergraduate English Major classrooms in one Kingdom of Saudi Arabia University. The data set comprised interviews with both of the teachers, focus groups with students, policy documents, curriculum documents and textbooks, surveys of student perceptions of English language and western culture, classroom observations and student written artefacts.

This thesis shows that, although the characterization of English teaching as operating with a "clash of civilizations" is perhaps too simplistic, a clear distinction can be made between opposing cultural forces which cause conflict in the Saudi Arabian University teaching and learning environment. This thesis provides a unique insight into the interplay of competing "Discourses" within this context.

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Thesis abstract

Social spaces, rural places: ageing-in-place in rural South Australia

Helen R. Feist

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Adelaide, Adelaide, Australia

Australia has an ageing population and a clear policy focus on ageing-in-place supported by family and community care, and service provision in the home. This thesis argues that place, space and availability of social support are important variables for how older people successfully age-in-place. The dual positioning of people in both physical and social space has important implications for understanding social behaviour and social support, particularly in rural areas where changing rural communities has been the focus of much attention.

This thesis explored place attachment, community connectedness and the social networks of 223 people aged 70 years and over living independently in small rural communities in the Murray Mallee region of South Australia. This was achieved by incorporating social, physical and temporal attributes of older individuals' lives in the data collection and analysis processes. A mixed method approach was adopted, using data from the 2006 Australian Census and face-to-face interviews with older people; with GIS technology enabling social networks to be examined spatially.

The findings demonstrate that social networks and therefore potential informal support are impacted upon by the dispersed geography of family ties. However, local community ties and a strong sense of place attachment provide some compensation for this, with the clear majority of other nominated network ties (groups, activities, friends, neighbours and services) being proximal. This creates a duality in the social networks of older people in rural areas – on the one hand they place emphasis on, and maintain strong links to, family despite increasingly dispersed family networks. On the other, a sense of place attachment and local community provides strong bonds for many older people, but may require higher levels of localised support to enable older rural people to successfully age-in-place.

Changes in network size, composition and modes of contact were found to be related to the physical changes associated with ageing and the nature of the rural environment in which the person lives. Changes in social networks occur over time; but as the consistent loneliness scores for all age groups suggest, not all change is necessarily negative. Many of the adjustments older people made to their social networks and patterns of daily life reflected adaptations that allowed them to remain living in the location of their choice and retain their independence. It is how those adaptations and choices are enabled by policy, service delivery and community support that may enhance the quality of ageing-in-place for older Australians living in rural settings.

By focusing on social environments through a spatial lens this study contributes to a better understanding of the issues of ageing-in-place in small rural communities for older people, service providers and intergenerational family groups and also for local rural communities.

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Archibald Liversidge
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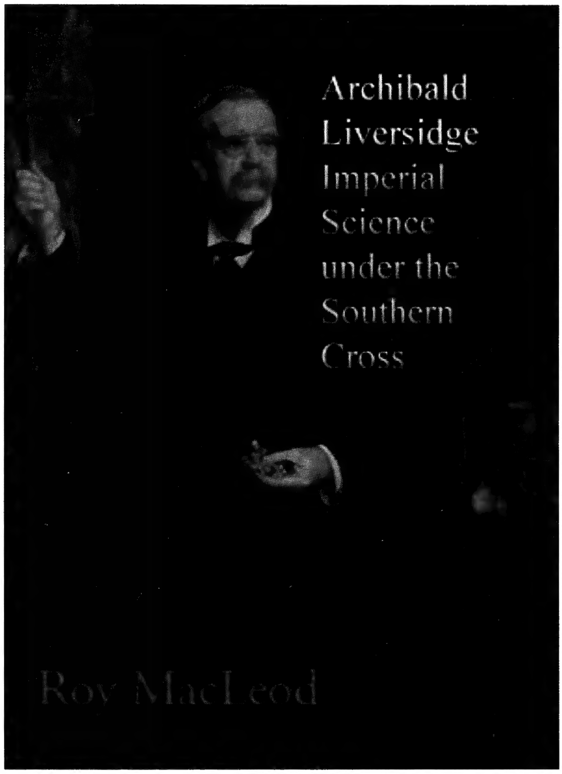

When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology And Mineralogy and by 1879 he had persuaded the University Senate to open a Faculty of Science. He became its first Dean in 1882.

In 1880, he visited Europe as a trustee of the Australian Museum and his report helped to establish the Industrial, Technological and Sanitary Museum which formed the basis of the present Powerhouse Museum's collection. Liversidge also played a major role in establishing the *Australasian Association for the Advancement of Science* which held its first congress in 1888.

This book is essential reading for those interested in the development of science in colonial Australia, particularly the fields of crystallography, mineral chemistry, chemical geology and strategic minerals policy.

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